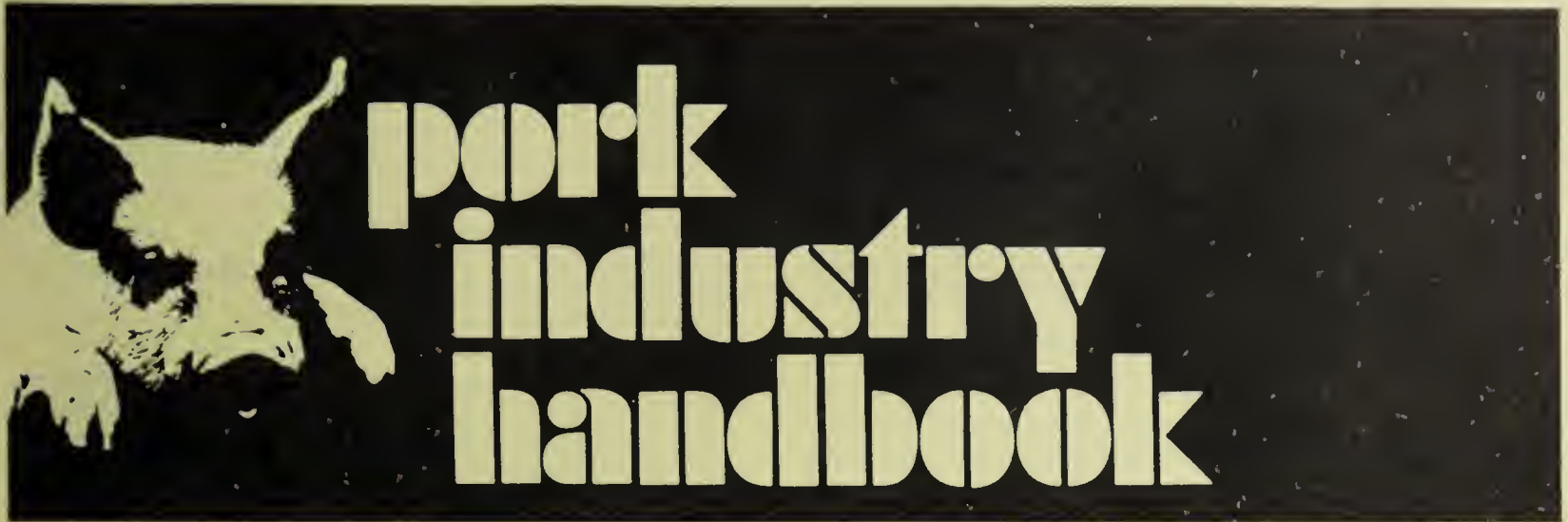




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Flushing Systems for Swine Buildings

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The two types of flushing systems used in swine production facilities are open-gutter flushing, for finishing and gestation buildings, and underslat flushing, which can be used in any swine building. Both systems use a sloped, shallow gutter that is flushed periodically to remove waste from the building to a lagoon. In open-gutter units, the periodic flushing attracts hogs to the channel and induces dunging, helping to "toilet train" them.

Basically, here's how a flushing system operates. A small-capacity pump transports lagoon water to a flush tank at the high end of the gutter in the building. The flush tank periodically dumps the water into the gutter (see Figure 1). Frequency of flush is determined by the rate water is

pumped into the tank. The tank is sized to contain enough water to "scour" wastes from the gutter. The spent flush water and waste re-enters the lagoon where it is treated and later reused for flushing. In areas where irrigation is practiced, many producers use fresh water for flushing instead of recycled water.

Who Should Consider Using Flushing Systems?

Flushing systems probably have the greatest appeal to those with farrow-to-finish operations, who feel they must handle swine waste as a liquid, and to those with suitable locations for lagoon construction. Producers who pur-

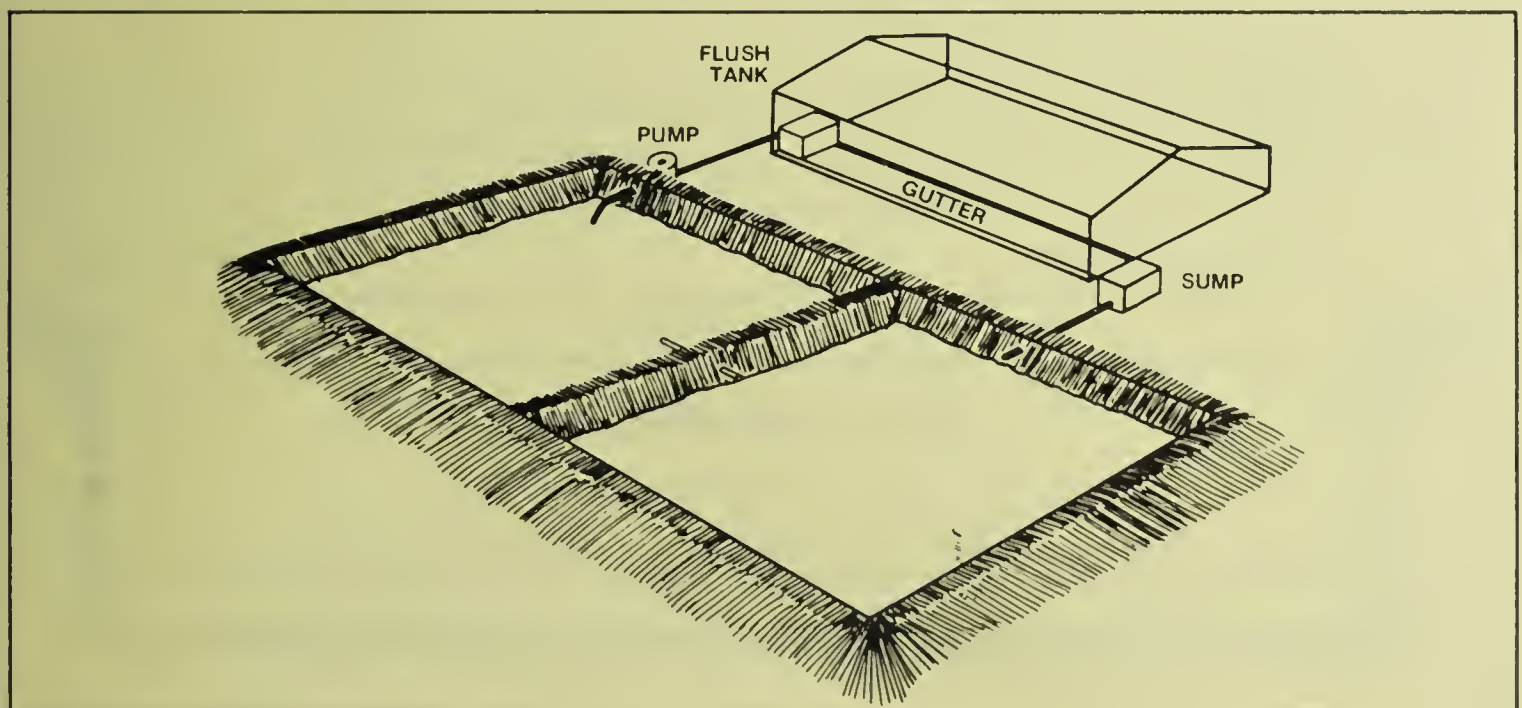


Figure 1. Perspective showing the components of a flush gutter system.

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chase feeder pigs for finishing may have some reservations about open-gutter flushing because of the possibility of disease transmission. In addition, producers using certain sulfa drugs should not use open-gutter systems for finishing hogs during the recommended drug withdrawal periods because of the potential for ingestion of drug residues from the lagoon water. It is often possible to use fresh water or underslat flush systems during the withdrawal period.

Advantages and Disadvantages of Gutter Flushing

Assuming that your present or proposed hog operation can accommodate a flushing system, what specifically are its advantages and disadvantages?

Advantages

- Lowers initial cost. Open-gutter flushing can reduce building cost by as much as 30% over a comparably sized, fully-slotted deep pit facility. However, the large lagoon required will reduce this savings to 10-15%. An underslat flushing system is usually comparable in construction cost to a conventional deep pit building.
- Can reduce odor problems. Frequent flushing of the waste can significantly reduce the characteristic "clinging" odor inside the confinement building.
- Adapts to building conversion. Some older buildings, especially dirt floor poultry buildings, are easily converted to include gutter flushing systems since a deep pit is not required.
- Saves fuel. Compared to deep pit systems requiring a tractor hauling system, flushing gutters with lagoon irrigation can use significantly less energy.

Disadvantages

- Greater nutrient loss. Lagoon-treated animal waste analysis shows a greater nutrient loss than for manure stored in a liquid manure pit under a slatted floor.
- Requires a relatively large land area. Using a lagoon for a flushing system takes up to 4-6 times more land area than the building itself. Many producers might have reservations about using land in this way.
- Interruptions to give medication. If medication is occasionally added to the drinking water, open-gutter flushing systems may have to be turned off for extended periods to force hogs to drink the medicated water, since they can and do drink some of the flushing water.
- Subject to mechanical problems. A flushing system has at least 2 mechanical components—flush tank and return pump—that must operate continuously. Like all mechanical devices, they are subject to breakdown.

- Lagoons are a potential odor source, particularly if not designed and operated properly.
- Possibility of disease transmission in open-gutter systems. Consider that lagoons with 2 cells are several times more effective in destroying disease organisms than single-cell lagoons.

Basic Parts of a Flushing System — Their Design and Operation

Gutter Design

How completely the waste is removed from the gutter depends on velocity, depth, duration, and frequency of the flush; and these factors are determined by the dimensions and slope of the gutter and by the rate flush water is added to the gutter. To adequately clean gutters, a flush velocity of at least 2.0 ft. per sec. is needed in open-gutters and at least 2.5 ft. per sec. in underslat gutters.

In an open-gutter, the initial depth of water should be at least 1½ in. with at least a 10 sec. flush duration. In an underslat gutter, a minimum of 2½ in. depth of flow with at least a 10 sec. flush is recommended. For channels longer than 125 ft. or with flushing devices which have a longer flush duration, such as siphons, increase the flush volume by at least 50% to provide the needed cleaning ability.

In most cases, the flush device determines the depth of water flow. For instance, a 3-in. siphon provides only water for about a 1 in. depth of flow in a 30-in. wide gutter, whereas larger siphons provide greater depths and can flush wider gutters. Most siphons release water to give a flush duration of about 30 sec. A "tipping bucket" flush tank can deliver a 3 in. depth of flow in almost any width gutter with a 5-10 sec. release, while the door opening and volume of a "trap door" tank can be designed to provide almost any depth of flow and flush duration.

Consider depth of flow in selecting gutter slope. Table 1 presents the recommended slopes for gutters of various widths and initial water flow depths. To achieve the same

Table 1. Minimum percent slope for flushed gutters.

Initial depth of flow (In.)	Open-gutter slope (%)	Underslat gutter slope (%)
1.5*	2.0	—
2	1.5	2.0
2.5†	1.25	1.5
3 or greater	1.0	1.25

* recommended minimum depth for open-gutter flushing

† recommended minimum depth for underslat flushing

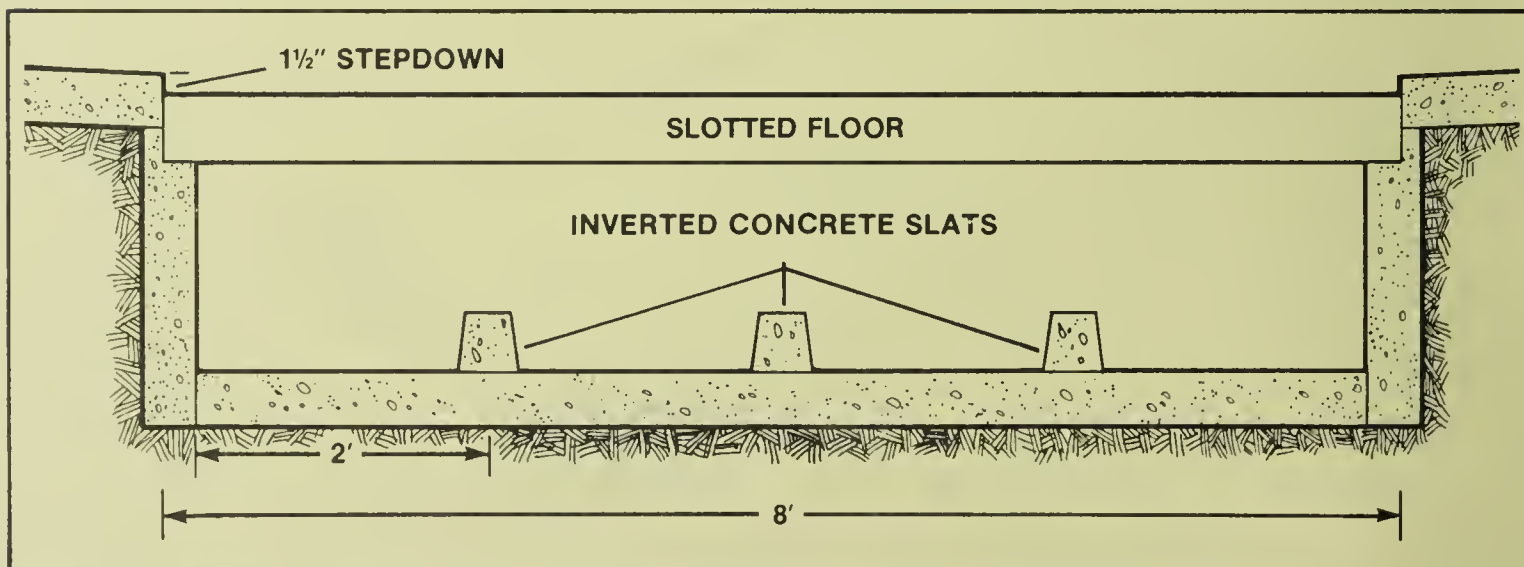


Figure 2. Cross-section of an underslat flushed gutter with dividers.

cleaning action, a steeper slope is required when depth of flow is shallow. Remodeled facilities using open-gutters can be designed for deeper channels (use 2 x 6s as forms) to increase depth of flow (e.g., 3-4 in.), thus permitting a more shallow slope. This minimizes excavation and construction problems in an existing building.

A good recommendation for open-gutter design is to allow a minimum of 1 sq. ft. of gutter area per 150 lb. of live-weight. Most open-gutters are a constant width—usually 30 or 40 in. with a depth of 3½ in. Channel depth should be at least 1 in. deeper than initial depth of flow. Open-gutter depths should not exceed 6 in.; a step that is too deep for the pig causes poor dunging habits.

For underslat systems, at least one-third of the floor should be slotted. Because underslat gutters do not have pig traffic to help suspend and break up the waste particles, slightly crown (¼ in.) the gutter, and give a smooth finish. Gutters wider than 4 ft. should have all but the first 20 ft. of their length divided up into gutter widths of 2-2½ ft. This helps keep flush water from channeling around waste deposits as it moves down the gutter. Inverted concrete hog slats work well for this purpose (see Figure 2).

Flush water picks up solids, causing the water to slow down as it moves through the gutter. This can be a problem in very long gutters. To overcome this, restrict gutters to about 125 ft. in length. Open-gutters can be longer if they are tapered and/or their slope is increased. Research at the University of Missouri showed that in a 132 ft. building, cleaning action was improved when the gutter was narrowed from 6 ft. at the upper end to 3 ft. at the lower end, and when the slope was varied down the length of the channel, instead of remaining a constant width and slope.

For open-gutters shorter than 125 ft., use a constant-slope gutter. For gutters from 125-250 ft., either use a tapered, variable-slope gutter, or slope both ends of the gutter so that they flush toward the middle of the building length. For gutters longer than 250 ft., consult a knowledgeable building engineer.

Wherever possible, use gravity to carry waste to the lagoon. Generally a sewer line 8 in. in diameter with a .5% slope or a line 6 in. in diameter with a 1% slope is sufficient to carry flushed waste to the lagoon. For very large tanks, greater than 500 gal., or where the same sewer must han-

dle several tanks, contact a knowledgeable engineer to see if a larger sewer line is needed.

Locate a sump pit at the discharge (or runoff) end of the flushing gutter if waste must be pumped to the lagoon. Volume of the sump should at least equal the flush tank volume.

Floor and Building Construction

The first step in constructing a swine building with gutter flushing is to establish the approximate grade for the building floor. For a variable-slope gutter, simply average the gutter slopes. Next consider placement of the footings. Using an engineer's level, establish the exact grade of the gutter along the length of the building. It is simplest and cheapest to slope the entire building the same as the gutter slope (Figure 3a). However, if constant ceiling height is desired, the foundation can be poured level at the sill, but with various depths as required by the sloping floor (Figure 3b).

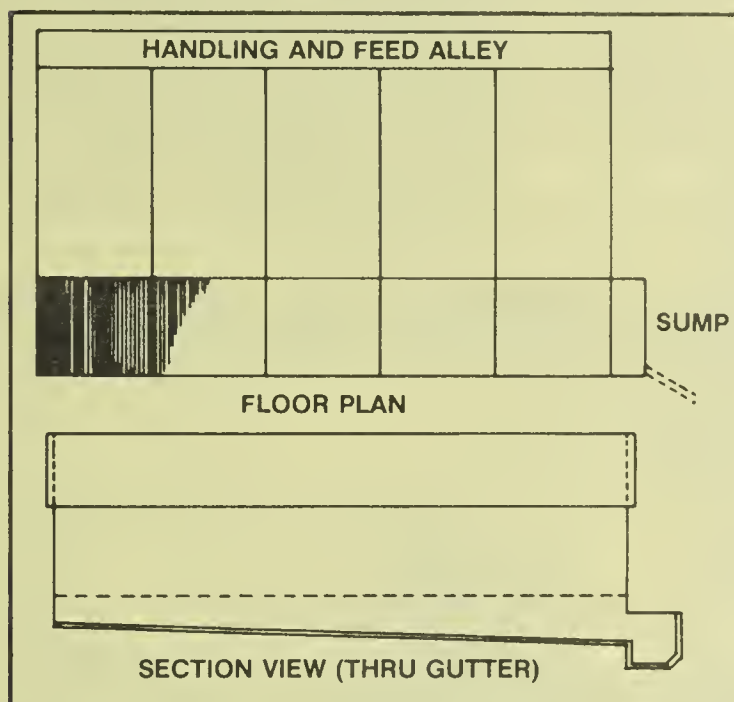


Figure 3b. Section view of building with underslat flushing gutter.

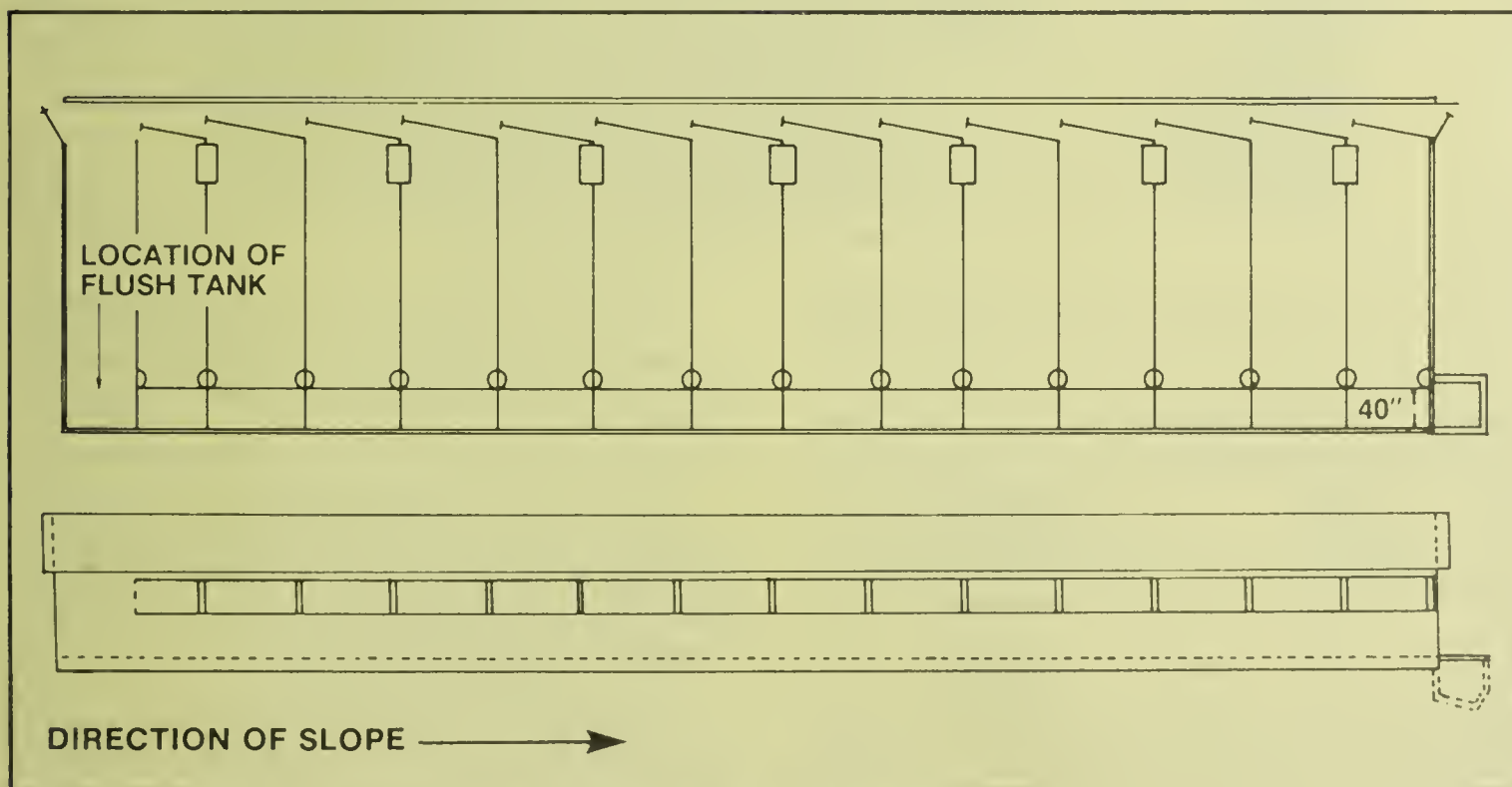


Figure 3a. Side view of finishing building sloped same percent as the flushing gutter.

With pole-type construction, the poles can be set, truss locations marked, and then the girders put in place. If the entire building is set at the gutter slope, the sidewalls are not perpendicular to the poles; however, this should not pose any significant problems since floor slope is not very great.

Flush Equipment Design

Flush Volume

Two flush volumes must be determined: the total volume required per day and the volume required per flush. The smaller the volume of water per flush, the more frequent the flushes should be. When too little water must pick up too much waste, the fluid characteristics change, and a dirty gutter results.

Total volume of flush water required per day for adequate cleaning is about 10 gal. per 100 lb. liveweight (Table 2). Total flush volume is used to size the recycle pump.

The required volume per flush, or flush tank size, depends on gutter width and desired depth of flow. Recommended tank volumes per ft. of flush gutter width are shown in Table 3. If you purchase commercial flush tanks, they may be rated on their discharge rate (see Table 4).

Table 2. Total daily required volume of flush water.

Type of animal	Flush volume (gal.)
sow and litter	35
nursery pig	4
finishing pig	15
gestation	25

Table 3. Minimum gallons of water required to flush gutters (in 10 sec.) at various depths of flow.

Initial depth of flow, in.	Gal./ft. of gutter width
1.5	30
2.0	40
2.5	45
3.0	50
3.5	60

Table 4. Tank discharge rates required to flush gutters at various depths of flow.

Initial depth of flow, in.	Discharge rate* (gal./min.) per ft. of gutter width
1.5	115-180
2.0	150-240
2.5	190-270
3.0	225-300

* Use flush durations longer than 10 sec. for the lower discharge rates.

Flush Frequency

How often to flush the gutters is determined by two factors—animal behavior characteristics and the solids-carrying capacity of the water. The minimum flushing frequency can be determined by dividing the daily flush volume (determined by the daily manure production) by the minimum volume per flush (determined by channel geometry). In general, open gutter channels are flushed every hour or two to maintain good dunging habits, while underslat gutters are flushed about four times a day. When underslat gutters are flushed manually only a few times per day, the volume per flush is determined by simply dividing the flush volume per day by the number of flushes per day. Odors from underslat floors can be controlled by flushing at least twice a day.

To insure cleaner pens, keep hogs crowded (4 sq. ft. per cwt. of animal), and use solid partitions except at the gutter area so that no other dunging habits are started. The management of an open gutter or underslat flush building is the same as for a partly slotted floor. Producers may need to floor-feed pigs during their first week in the building to help establish good dunging habits.

In summer, hogs lie in the gutter and block the flow of water, but this does not hurt the efficiency of the flushing operation. Underslat gutters should be flushed at least 2 times a day, but preferably every hour. In underslat systems, a 1 ½ in. stepdown to the slats from the bedded area will usually help establish desired dunging habits.

Flush Tanks

Four types of flush tanks have been developed to provide the required flush volumes: the automatic siphon tank, the tipping bucket, the trap door tank, and the manual dump tank.

Automatic siphon tank: Designed and in use at Iowa State University since 1969, this type of tank has the singular advantage of no moving parts (see Figure 4). As the tank slowly fills with water, an air bubble trapped under the bell is forced out the siphon pipe until it triggers the siphoning action. An automatic siphon tank can be placed above the pens, thus eliminating floor space requirements. See AED-17, "Three-Inch, 150 Gallon Siphon Flush Tank," available from the Midwest Plan Service (MWPS) at Iowa State University, Ames, Iowa, for construction details.

Kansas State University has developed an 8 to 24 in. automatic siphon which can handle very large volumes of water. This flush unit uses a small 2-in. siphon to trigger the larger siphon. This large siphon is well suited to flushing wide, underslat gutters.

Tipping bucket tank: Michigan State University has designed a tipping bucket which dumps when it fills to a depth where the center of gravity of the water volume overbalances the pivot point. Because the water discharges all at once, flushing velocity and depth are high and can cover a very wide gutter (8-10 ft.), if necessary (see Figure 5.).

Trap door tank: A University of Missouri innovation, this flush tank has more moving parts than either of the above methods, but allows greater design flexibility because both tank volume and trap door can be modified to meet individual needs. Care and precision are necessary to get a water-tight seal around the door.

Manual flush tank: The manual tank is best suited to twice a day flushing in underslat systems. These are found most commonly in farrowing houses where the operator is present several times a day. Figure 6 shows a simple but effective manual flush tank.



Figure 4. An elevated automatic siphon tank being used in a farrowing house.

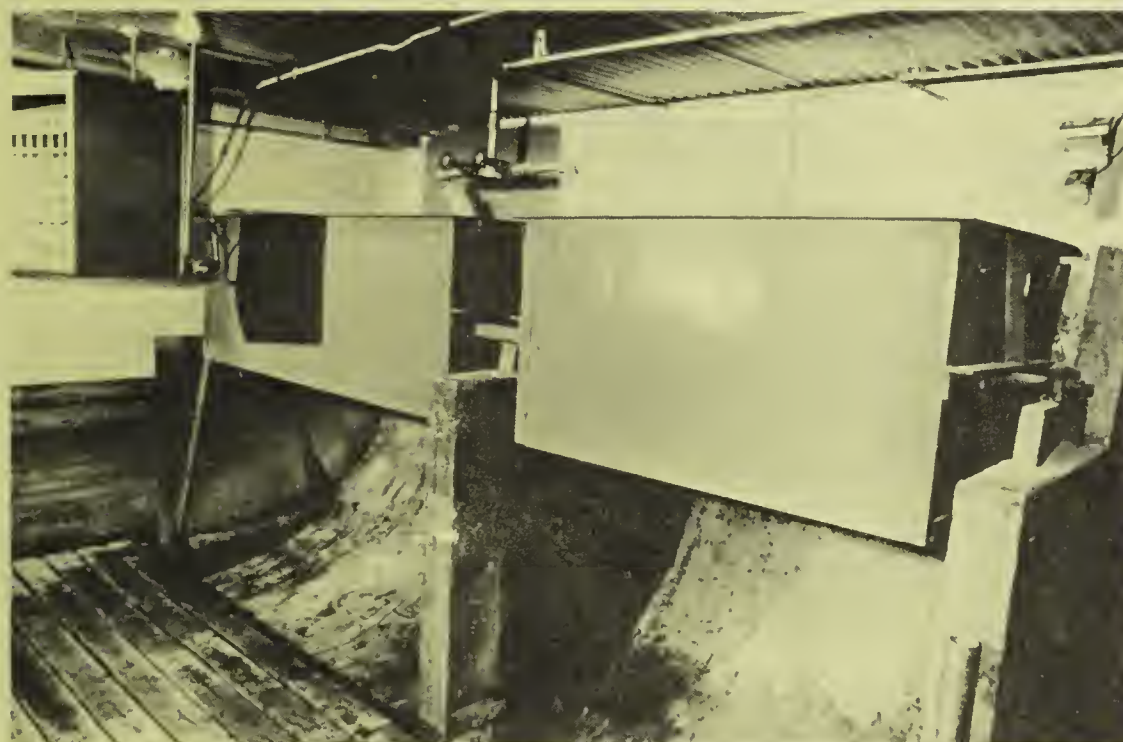


Figure 5. Tipping bucket tank used for flushing underslat gutters.

Waste Treatment Lagoons

A properly designed and operated lagoon is essential to the success of a flushing system (see Figure 7).

Although a single stage lagoon can operate satisfactorily in a flushing system, a two-stage lagoon is preferred to minimize odor and disease potential.

The design criteria for lagoons used with flushing systems are the same as for conventional swine waste lagoons. See PIH-62, "Lagoon Systems for Swine Waste Treatment," or MWPS-18, "Livestock Waste Facilities Handbook," available from Midwest Plan Service, for design information on lagoons for your area.

Pumps and Pipes

Pumps transport effluent from the lagoon to the flush tank and, if needed, from the sump at the end of the gutter to the lagoon.

Lagoon-to-Flush-Tank-Pump

The pump used to fill the flush tank is generally very small. For example, a 10 gal. per min. pump is sufficient for two 300-gal. tanks with hourly flushing.

A plastic fitted, nonclogging type of pump with high quality seals that can be easily serviced is recommended. Slower-speed pumps (1725 rpm or less) cost more initially but usually last longer than high-speed pumps (3450 rpm). Because of their seemingly short service life (6-12 mo.), it is a good idea to keep several spare replacement impellers on hand.

Do not use pumps with metal impellers or any metal parts in contact with the water being pumped. Salts in lagoon water precipitate on the metal and eventually plug the pump. Avoid sharp turns in the supply pipe because they add to pressure drop and create turbulence conducive to salt precipitation. Regular addition of dilution water to the

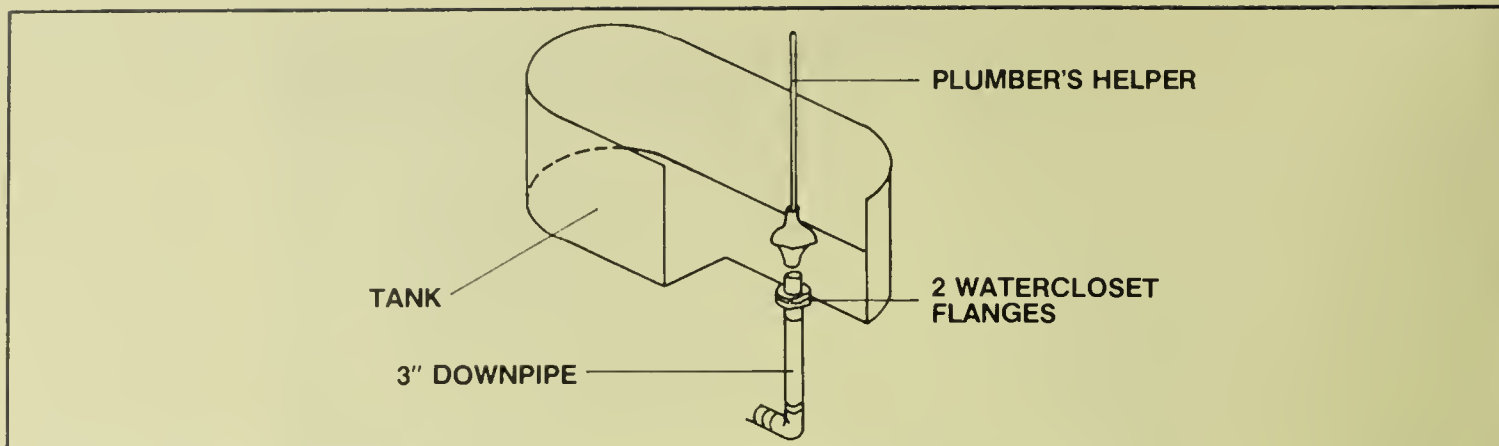


Figure 6. Cut-away view of manual flush tank.

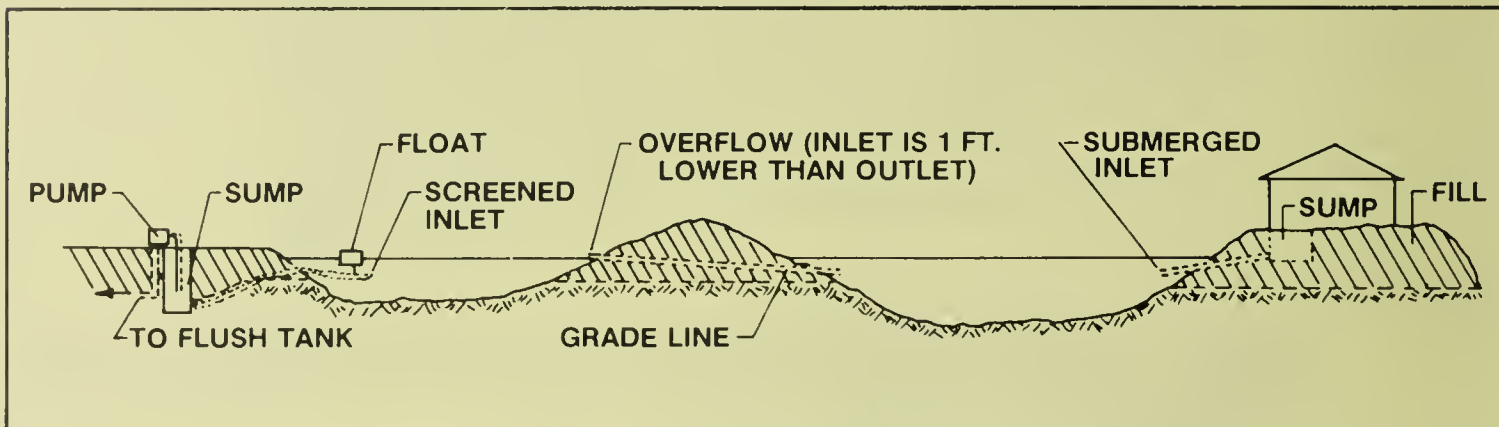


Figure 7. Cut-and-fill construction for a two-stage swine waste lagoon system.

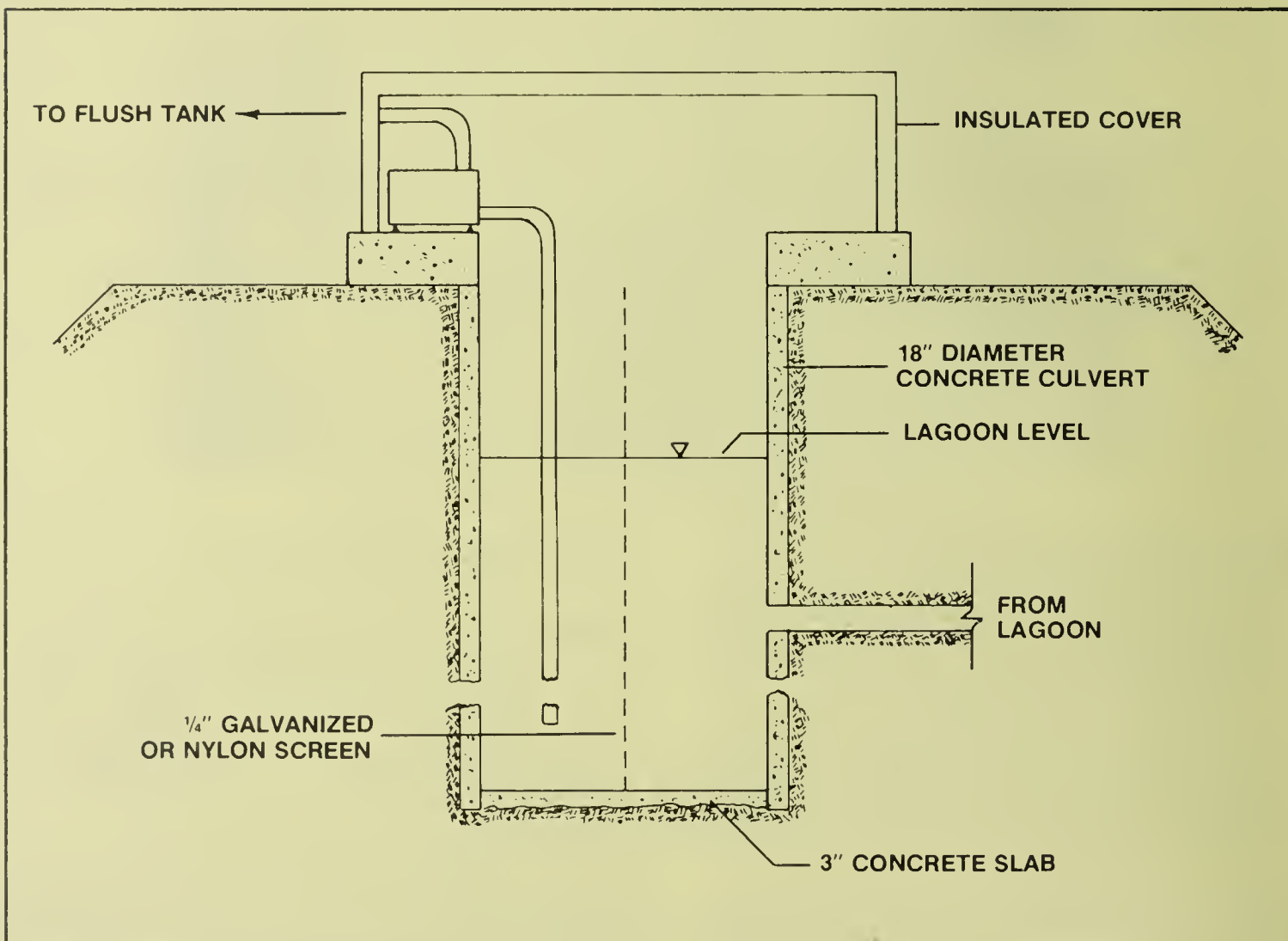


Figure 8. Diagram of a wet-well configuration.

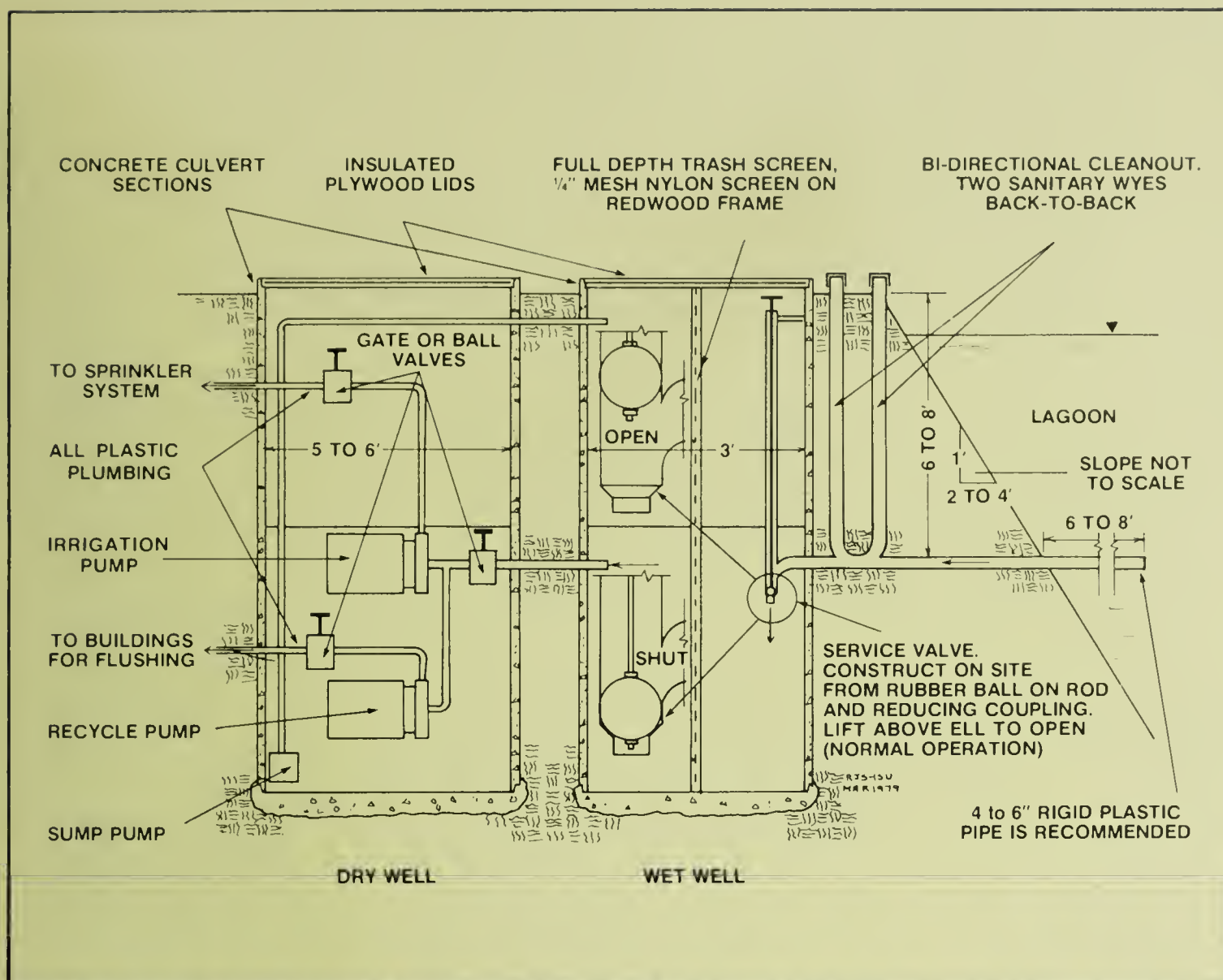


Figure 9. Pumping from a lagoon using a wet well and dry well configuration.

lagoon and removal of salts by irrigation will reduce problems. In most areas of the U.S., the volume of dilution from water wastage and rainfall runoff should equal the volume of waste added. Various treatments (dilute acetic or hydrochloric acids) have been used to dissolve salt deposits, but the best solution is to avoid the problem through proper design and dilution. Mixing and use of acids is hazardous and must be done with caution.

A lagoon-to-flush-tank pump can be placed on the lagoon bank in an insulated enclosure or in a wet well sunk in the bank (see Figures 8 and 9). The pump must be protected from freezing weather.

The intake pipe from lagoon to wet well should be at least 1 in. greater in diameter than the outlet on the return pump. The intake should be at least 18 in. below the lagoon surface, with inlet openings placed several feet from the bank and as far away as practical from where the waste enters the lagoon.

Sump-to-Lagoon Pump

If the pump is needed to lift effluent from building to lagoon, it should be a commercial grade sewage lift type activated with a float switch.

A 3 in. pump should be satisfactory for most operations. Size of the line from pump to lagoon should be the same as the pump discharge to prevent solids from settling in the pipe. Size the sump no larger than the largest flush tank to avoid solids settling.

Piping

The pipe from lagoon to flush tank can be relatively inexpensive polyethylene and, if possible, should be one continuous piece. See Table 5 for determining the size you will need.

Table 5. Recommended pipe sizes for various flow rates.

Pump capacity Gal./Min.	Pipe diameter In.
5	.75
10	1.0
20	1.5
30	2.0
40	2.5

Reference to products in this publication is not intended to be an endorsement to the exclusion of others which may be similar. Persons using such products assume responsibility for their use in accordance with current directions of the manufacturer.

Worksheet For Designing and Equipping A Gutter Flushing System For Swine

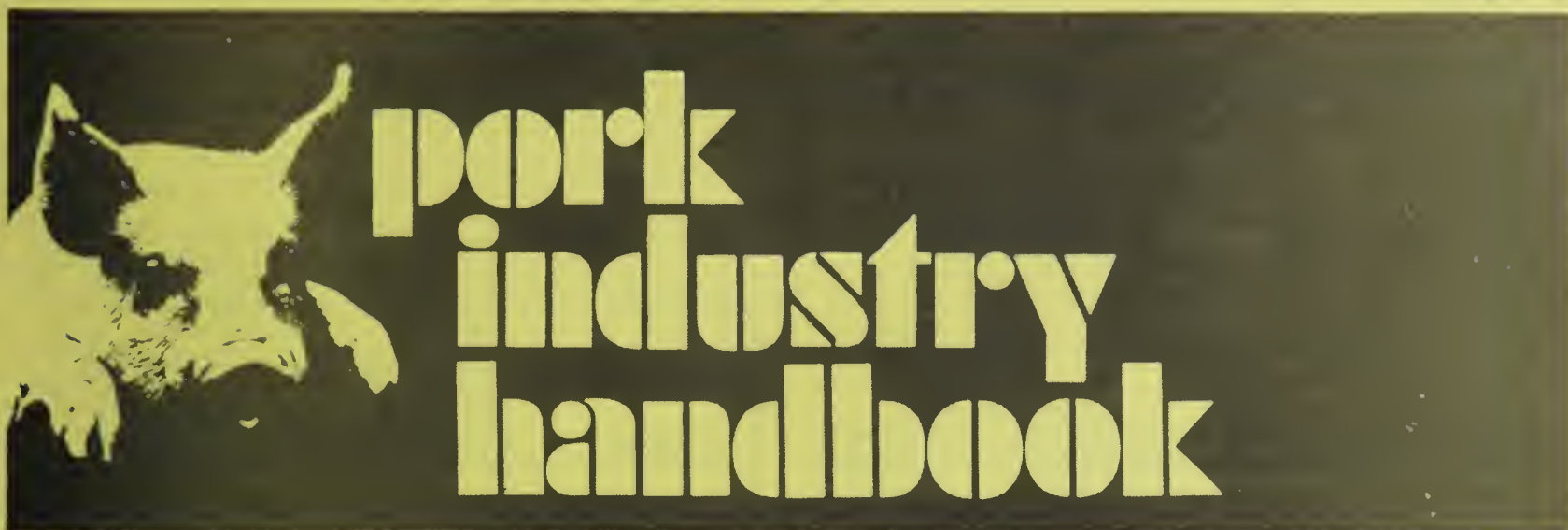
Example Situation

A farmer wants to construct a 250 head hog finishing unit to accommodate open-gutter flushing. The building will be 28 ft wide x 84 ft. long with constant-width gutter on one side. Pen size will be 8 ft. x 24 ft. with about 25 pigs per pen.

From the above assumptions and the information given in this publication, design his open-gutter system and determine types and sizes of flushing equipment needed.

Calculations	Our example	Your situation
1. Determine dimensions of gutters.		
a. Gutter width: Minimum gutter area per hog (1 sq. ft.) x no. hogs per pen (25)/pen width (8 ft.). This is a minimum; to insure better cleaning, the farmer decides on a 40 in. width. (Or gutter width in ft. = $40 \text{ in.} \div 12 \text{ in./ft.} = 3.33 \text{ ft.}$)	= 40 in.	
b. Initial depth of flow: See Table 1 for recommendations.	= 1.5 in.	
c. Gutter slope: From Table 1.	= 2.0%	
2. Determine flush volume and tank capacity:		
a. Required daily flush volume: No. finishing hogs (250) x gal. of flush water per head per day (15 gal. from Table 2).	= 3750 gal.	
b. Minimum flush volume (determined by channel geometry): From Table 3 (30 gal./ft. of gutter width); if channel is longer than 125 ft., increase volume by 50%. Total flush volume: gutter width (3.33 ft.) x 30 gal./ft. = 100 gal.	= 100 gal.	
c. Flush volume for flush intervals longer than 2 hrs.: If time between flushes must be longer than 2 hrs., size tank accordingly. For example, if tank can be flushed only four times a day, tank capacity should be 1/4 the total flush volume (step 2 a.): e.g., $3750 \div 4 = 937 \text{ gal.}$	= 937 gal.	
3. Determine size of return pump (lagoon to flush tanks).		
a. Pump capacity to supply required flush volume: Step 2 a. ($3750 \text{ gal.} \div 1440 \text{ minutes per day}$). If a flexible impeller pump is used, match the pump speed to the desired flow rate with a belt drive. Driving such pumps at 500 rpm or less improves the lifetime significantly.	= 2.6 gpm*	
b. Minutes between flushes: Step 2 b. [(100 gal.) x no. tanks per pump (1)] $\div$ Step 3 a. (In this example, 2.6 gpm. However, assume a 5 gpm. pump is available and will be used.)	= 20 min.	
4. Determine size of return pipe (lagoon to flush tanks).		
a. Select from Table 5 using pump flow rate from Step 3 a.	= 3/4 in.	

*Use nearest pump size available.



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Fertilizer Value of Swine Manure

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Swine manure contains fertilizer nutrients that can be utilized to support efficient crop production and enhance soil chemical and physical properties. Thus, manure can be an asset to a swine operation when managed to maximize the use of the available nutrients for fertilizer. The purpose of this fact sheet is to provide the swine producer with pertinent information on (1) the fertilizer nutrient content of swine manures available for land application, (2) how to determine manure application rates and the need for supplementary fertilizer for maximum crop production, and (3) related management techniques for maximizing the fertilizer potential of swine manure on the farm.

Factors Affecting Fertilizer Value of Manure, and Recommendations for Application

The type and amount of nutrients in swine manure and their eventual availability to plants varies considerably from farm to farm. Some factors affecting nutrient value of manure are: type of ration fed to swine; method of manure collection and storage; amount of feed, bedding and/or water added; time and method of application; soil characteristics and type of crop to which the manure is applied; and climate.

Increasing levels of additives (copper, arsenic, etc.) and inorganic salts (sodium, calcium, potassium, magnesium, phosphate, chloride, etc.) in swine rations will change concentrations of these elements in manure. There is concern about the potential toxic effects of elevated concentrations of heavy metals and salts in soil and plants as a result of high application rates of manure to the land. Routine soil tests and manure analysis on your farm are recommended to monitor the balance of nutrients in the soil, especially on land receiving heavy manure applications.

Bedding and water that get into manure dilute its nutrient concentration, thus lessening its value per ton or gallon when applied to the land. Feed spillage, on the other hand, will increase manure nutrient concentration for land application. Feed spillage and inadequate agitation may cause sludge buildup and difficult removal in liquid manure systems.

The type of housing and/or waste handling system greatly affects the nitrogen (N) concentration of swine manures (Table 1). Major N loss occurs when manure is dried by sun and air movement or is leached by rain as would be the case in an open lot system. In contrast, comparatively little N is lost from manure in a completely covered feedlot when a manure pack or liquid pit storage system is used. Loss of N is greatest in long-term treatment or storage systems such as oxidation ditches or lagoons.

Table 1. Approximate nitrogen losses from swine manure as affected by handling and storing methods.

Handling, storing methods	Nitrogen loss*
	%
Solid systems	
Manure pack	35
Open lot	55
Liquid systems	
Anaerobic pit	25
Oxidation ditch	60
Lagoon	80

*Based on composition of manure applied to the land vs composition of freshly excreted manure.

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Phosphorus (P) and potassium (K) losses are minimal (5-15%) for all but open lot and lagoon manure handling systems. In an open lot, from 40 to 50% of the P can be lost to runoff and leaching. However, most of the P and K can be retained by runoff control systems (settling basins, detention ponds) for fertilizer use. With a lagoon, from 50 to 80% of the P in manure can settle out in the sludge layer and, thus, be unavailable if only liquid is applied to the land.

Maximum nutrient benefit is realized when manure is incorporated into the soil immediately after land application (Table 2). Soil incorporation of manure not only minimizes N loss to the air and/or runoff but also allows the soil microorganisms to start decomposing organic matter in manure, thus making nutrients available to the plant sooner. In addition, incorporation of manures beneath the soil surface minimizes potential odor problems. Generally, P and K losses are negligible and are not affected by method of application; however, incorporation of manure would minimize P and K losses in the event of surface runoff from manured land. Manure should be applied as uniformly as possible to prevent local concentrations of ammonium-N or other inorganic salts that can reduce germination and yields.

Table 2. Approximate nitrogen losses from swine manure to the air as affected by application method.

Application method	Type of manure	Nitrogen loss*
		%
Broadcast <i>without</i> cultivation	Solid	20
	Liquid	25
Broadcast <i>with</i> cultivation†	Solid	5
	Liquid	5
Knifing	Liquid	5
Irrigation	Liquid	30

*%of total nitrogen in manure applied which was lost within 4 days after application.

†Cultivation immediately after application.

Application of liquid manure near the planting date will maximize nutrients available for plant growth, especially in high rainfall, porous soil-type, rapid percolation areas. Lowered germination and reduced seedling growth could occur, however, if planting takes place immediately after heavy manure applications. This would come about from salt accumulation near the soil surface. As an alternative, late fall or winter applications may be desirable because of labor availability, field conditions, etc. Even though fall-winter applications may result in 5-10% total N loss, more time in the field allows soil microorganisms time to more fully decompose manure and release nutrients for the following cropping season use. This is especially advantageous for solid manure which contains much organic matter.

Table 3. N, P₂O₅ and K₂O utilization by various crops.

Crop	Expected	N	P ₂ O ₅	K ₂ O
	yield			
lb./acre				
Corn	80 bu.	121	42	77
	100 bu.	160	60	120
	150 bu.	185	80	215
	180 bu.	240	100	240
Corn silage	16 tons	130	45	102
	32 tons	200	80	245
Soybeans	30 bu.	123	32	52
	40 bu.	180	45	80
	50 bu.	257	48	120
	60 bu.	336	65	145
Grain sorghum	4 tons	250	90	200
Wheat	40 bu.	70	30	50
	60 bu.	125	50	110
	80 bu.	186	54	162
Oats	80 bu.	75	35	95
	100 bu.	150	55	150
Barley	65 bu.	74	32	63
	100 bu.	150	55	150
Alfalfa	4 tons	180	40	180
	8 tons	450	80	480
Orchardgrass	6 tons	300	100	375
Bromegrass	5 tons	166	66	254
Tall fescue	3.5 tons	135	65	185
Bluegrass	3 tons	200	55	180
Coastal Bermuda grass	4 tons	225	40	160
	10 tons	535	145	410
Clover-grass	4.5 tons	185	60	175
	6 tons	300	90	360
Sugar beets	30 tons	275	85	550
Rice	2.25 tons	110	45	110
	3.5 tons	112	60	168
Timothy	4 tons	150	55	250
Pangola grass	12 tons	299	108	430
Sorghum-sudan grass	8 tons	319	122	467

Table 4. Approximate average (and range) dry matter and fertilizer nutrient composition of swine manures at time applied to the land.*

Manure handling system	Dry matter	Available N†	P ₂ O ₅ ‡	K ₂ O§	Total N#
Solid	%		lb./ton manure		
Without bedding	18 (15-20)	7 (6-9)	9 (7-13)	8 (6-10)	10 (9-11)
With bedding	18 (17-20)	6 (5-8)	7 (5-10)	7 (6-9)	8 (7-10)
Liquid	%		lb./1,000-gal. manure		
Anaerobic pit	4 (2-7)	26 (21-31)	27 (13-30)	22 (12-30)	36 (28-55)
Oxidation ditch	2.5 (1-4)	16 (12-22)	27 (10-30)	22 (10-24)	24 (18-34)
Lagoon**	1 (.3-2)	4 (2-5)	2 (1-4)	4 (2-6)	4 (3-6)

*Application conversion factors: 1 bu. manure spreader = 40-60 lb. solid manure; 1,000 gal. = about 4 tons; 27,154 gal. = 1 acre in.

†Primarily ammonium-N and 35% organic nitrogen which is available to the plant during the growing season.

‡To convert to elemental P, multiply by 0.44.

§To convert to elemental K, multiply by 0.83.

#Ammonium-N plus organic N, which is slow releasing.

**Includes feedlot runoff water and is sized as follows: *single cell*—2 cu.ft./lb. animal weight; *two-stage anaerobic* (cell 1)—1-2 cu.ft./lb. animal weight; and *aerobic* (cell 2)—1 cu.ft./lb. animal weight.

Table 5. Approximate nutrient value of swine manure per animal unit (1,000-lb. average liveweight) per year.*

Handling and disposal method	Total N	P ₂ O ₅	K ₂ O
lb./animal unit			
Manure pack			
Broadcast	84	107	124
Broadcast & cultivation	102	107	124
Open lot			
Broadcast	58	61	80
Broadcast & cultivation	70	61	80
Manure pit			
Broadcast	95	111	119
Knifing	124	111	119
Irrigation	92	111	119
Lagoon			
Irrigation	24	25	89

*Based on initial nutrient content and subsequent losses due to method of handling and disposal.

The chemical and physical properties of soil, such as water infiltration rate, water-holding capacity, texture and total exchange (nutrient-holding) capacity, also affect how much manure can be safely applied to land. Heavy-textured soils have low water infiltration rates; therefore, the rate at which liquid manure, especially lagoon effluent, can be applied without runoff may be restricted to the intake rate of the soil. Coarse-textured soils, on the other hand, are quite permeable and can accept higher rates of liquid manure applications without runoff. But because most coarse soils have a very low exchange (nutrient-holding) capacity, application may have to be restricted to smaller amounts during the growing season to minimize

the chance of soluble nutrients entering ground water. Organic matter in the manure is decomposed more rapidly in light-textured than heavy-textured soil and during warm moist conditions rather than cold and dry conditions. However, heavier textured soils will retain the nutrients longer in the upper profile (where plants can get them).

Table 3 shows the amount of N, P₂O₅ and K₂O that various crops utilize during the growing season. Grasses and cereal grain crops generally respond most favorably to the nutrients (especially N) in manure. For greatest dollar benefit, therefore, apply manure to land in corn, small grains and sorghum; then, if more is available, to land cropped to forages and pasture land.

Not all manure nutrients are readily available to a crop in the year of application. To be utilized by plants, nutrients must be released from the organic matter in manure and be in a water-soluble form. Manure nitrogen is in ammonium and organic forms. Potentially, all of the ammonium-N, except that lost to the air, can be utilized by plants in the year of application. Nitrogen in the organic form, however, must be "released" before plants can use it. From 20 to 50% of this organic N may become available the year of application with some N carried over and available the next cropping season. Nearly all of the P and K in manures are available for plant use the year of application. Table 4 shows the average and range percent dry matter and fertilizer nutrient composition of solid and liquid swine manures at the time of land application (wet basis). The nutrient content of manure from your farm might differ considerably from the values presented here; however, these figures can serve as a guideline in determining land application rates if a nutrient analysis of the manure is not available. Table 5 shows the annual approximate fertilizer value of manure from your swine operation expressed as pounds per animal unit (1,000 lb. of live animal weight).

Determining How Much Swine Manure Can Be Applied

If you know the fertilizer needs of the crops grown on your land (Table 3) and the approximate nutrient value of the swine manure at the time of application from your farm (Table 4), you can determine how much manure can be applied beneficially to the land and if additional commercial fertilizer will be needed for efficient crop production. In addition, knowing the crop nutrient needs (Table 3) and the approximate amount of fertilizer nutrients available from the swine operation per year (Table 5), you can determine how much land is needed for manure disposal. Swine manure should be applied to the land at such a rate that the amount of available nutrients does not greatly exceed the amount removed by the growing crop. This not only insures efficient use of manure nutrients but it also minimizes the chances of their leaching into ground water. Check with local regulatory agencies concerning specific restrictions on land application rates in your area.

The Worksheet

A worksheet (with example) is provided to help you arrive at the proper application rates. The phosphorus and potassium analysis of a soil test, along with the crop nutrient requirement figures in Table 3, should be used to adjust these rates to your soil conditions. In addition, a laboratory analysis is the most accurate way to ascertain the nutrient value of the manure from your swine operation. For names of commercial laboratories that provide soil and/or manure analyses, contact your local Agricultural Extension Office. Check with the laboratory for specific procedures on obtaining and sending representative samples for analyses.

The worksheet calculations show that the proper manure application rate on 150-bu. corn land would be 9,773 gal. per acre per year if using the manure as a complete fertilizer or 2,963 gal. if maximizing the fertilizer value (Step 3a). In the case of our worksheet example, this 1,500-head swine feeding operation would require a minimum of 96 acres or a maximum of 260 acres for manure disposal (Step 5d).

If you apply manure to maximize its fertilizer value, the worksheet indicates an additional 108 lb. of N and 150 lb. of K₂O are needed per acre to meet corn nutrient requirements (Step 4b). This can be supplied with commercial fertilizer as follows: 240 lb. of urea (45% N) or 132 lb. of anhydrous ammonia plus 250 lb. of 0-0-60 potash.

Some additional management recommendations to help insure safe and effective application of manure to cropland follow:

- Unless immediately incorporated into the soil, surface apply manure at reasonable distances from streams, ponds, open ditches, neighboring residences and public buildings to minimize runoff and odor problems. Use good management to avoid neighbor complaints.
- To minimize any odor problems, spread raw manure frequently, especially during the summer. Spread early in the day when the air is warming up and rising rather than later when the air is cooling and settling, and do not spread on days when the wind is blowing toward populated areas or when the air is still and seems to hang.
- During frozen ground conditions, apply manure only to relatively level or flat land.
- Agitate or mix liquid manures thoroughly in pits to facilitate removal of settled solids and thus insure uniform application of the nutrients.
- Consider irrigating dilute manures (lagoon or runoff liquids) during dry weather to apply needed water and nutrients to growing crops.
- When irrigating manure on growing crops, wash the plants off with clean water to avoid leaf burn.
- Avoid spreading liquid manure on water-saturated soils where runoff is apt to occur.
- In arid regions, the salt content of manure is of potential concern. Sufficient water must be applied sometime during the year to avoid soluble ion accumulation in the root zone.
- Use good safety measures when removing manure from tanks or pits. Because of oxygen deficiency or toxic gas accumulation, avoid entering storage structures when agitating the liquid manure.

Worksheet for Determining Animal Manure Application Rates and Size of Disposal Area

Example: A swine producer has a 1,500-head animal unit capacity growing-finishing operation (average weight 125 lb. per animal) in an enclosed confinement building. Manure is handled in a liquid pit and is surface-applied to the land without immediate cultivation. To maximize use of the manure as fertilizer, what should be the manure application rate, how much supplemental commercial fertilizer will be needed, and how many acres of cropland can utilize the manure?

Calculations	Example	Your situation
1. Determine nutrient needs of the crop.		
a. Crop grown on the land receiving the manure.	<u>150 bu. Corn</u>	
b. Nutrient needs of that crop, expressed as pounds per acre (from Table 3).		
	N = <u>185 lb.</u>	
	P ₂ O ₅ = <u>80 lb.</u>	
	K ₂ O = <u>215 lb.</u>	
2. Determine nutrient value of the manure.		
a. Type of manure to be applied.	<u>Anaerobic Pit</u>	
b. Nutrient value of the manure, expressed as pounds per ton for solid handling systems or as pounds per 1,000 gal. for liquid handling systems (from Table 4, or recent laboratory analysis.)		
	N = <u>26 lb./1000 gal.</u>	
	P ₂ O ₅ = <u>27 lb./1000 gal.</u>	
	K ₂ O = <u>22 lb./1000 gal.</u>	
3. Determine amount of manure to meet crop needs.		
a. Manure to meet the crop's N, P ₂ O ₅ and K ₂ O requirements, expressed as tons per acre for solid handling systems or as 1,000 gal. per acre for liquid handling systems.		
N value from 1.b. ÷ N value from 2.b. =	<u>7.115</u>	
P ₂ O ₅ value from 1.b. ÷ P ₂ O ₅ value from 2.b. =	<u>2.963</u>	
K ₂ O value from 1.b. ÷ K ₂ O value from 2.b. =	<u>9.773</u>	
b. If the manure is to be used as a complete fertilizer, select the <i>highest</i> of the three values as your application rate per acre. If your aim is to maximize use of the swine manure, select the <i>lowest</i> of the three values, then supplement with commercial fertilizer to supply the remainder of the two nutrients still deficient.	<u>2.963</u>	

Calculations	Example	Your situation
4. Determine supplemental fertilizer needed.		
a. Amount of N, P ₂ O ₅ and K ₂ O, expressed as pounds per acre, supplied at the manure application rate selected in 3.b.		
N value from 2.b. x Application rate from 3.b. =	<u>77 lb./A</u>	<u> </u>
P ₂ O ₅ value from 2.b. x Application rate from 3.b. =	<u>80 lb./A</u>	<u> </u>
K ₂ O value from 2.b. x Application rate from 3.b. =	<u>65 lb./A</u>	<u> </u>
b. Amount of commercial fertilizer needed, expressed as pounds per acre, to meet deficient crop nutrient requirements.		
N value from 1.b. - N value from 4.a. =	<u>108 lb./A</u>	<u> </u>
P ₂ O ₅ value from 1.b. - P ₂ O ₅ value from 4.a. =	<u>0 lb./A</u>	<u> </u>
K ₂ O value from 1.b. - K ₂ O value from 4.a. =	<u>150 lb./A</u>	<u> </u>
5. Determine total cropland acreage which can be fertilized by the manure produced.		
a. Average animal units per year, expressed as 1,000 lb. liveweight, in the livestock enterprise (average weight per animal x average number of animals per year ÷ 1,000).		
<u>125 lb. x 1500 ÷ 1000 = 187 1/2</u>	<u>= 187 1/2 a.u.</u>	<u> </u>
b. Annual manure nutrient production per animal unit, expressed as pounds per animal unit (from Table 5; manure pit - broadcast).		
N =	<u>95 lb./a.u.</u>	<u> </u>
P ₂ O ₅ =	<u>111 lb./a.u.</u>	<u> </u>
K ₂ O =	<u>119 lb./a.u.</u>	<u> </u>
c. Total animal manure nutrient production from the livestock enterprise, expressed as pounds per year.		
Animal units from 5.a. x N value from 5.b. =	<u>17,812 1/2 lb.</u>	<u> </u>
Animal units from 5.a. x P ₂ O ₅ value from 5.b. =	<u>20,812 1/2 lb.</u>	<u> </u>
Animal units from 5.a. x K ₂ O value from 5.b. =	<u>22,312 1/2 lb.</u>	<u> </u>
d. Total cropland area, which can be fertilized, expressed as acres.*		
N value from 5.c. ÷ N value from 1.b. =	<u>96 A</u>	<u> </u>
P ₂ O ₅ value from 5.c. ÷ P ₂ O ₅ value from 1.b. =	<u>260 A</u>	<u> </u>
K ₂ O value from 5.c. ÷ K ₂ O value from 1.b. =	<u>104 A</u>	<u> </u>

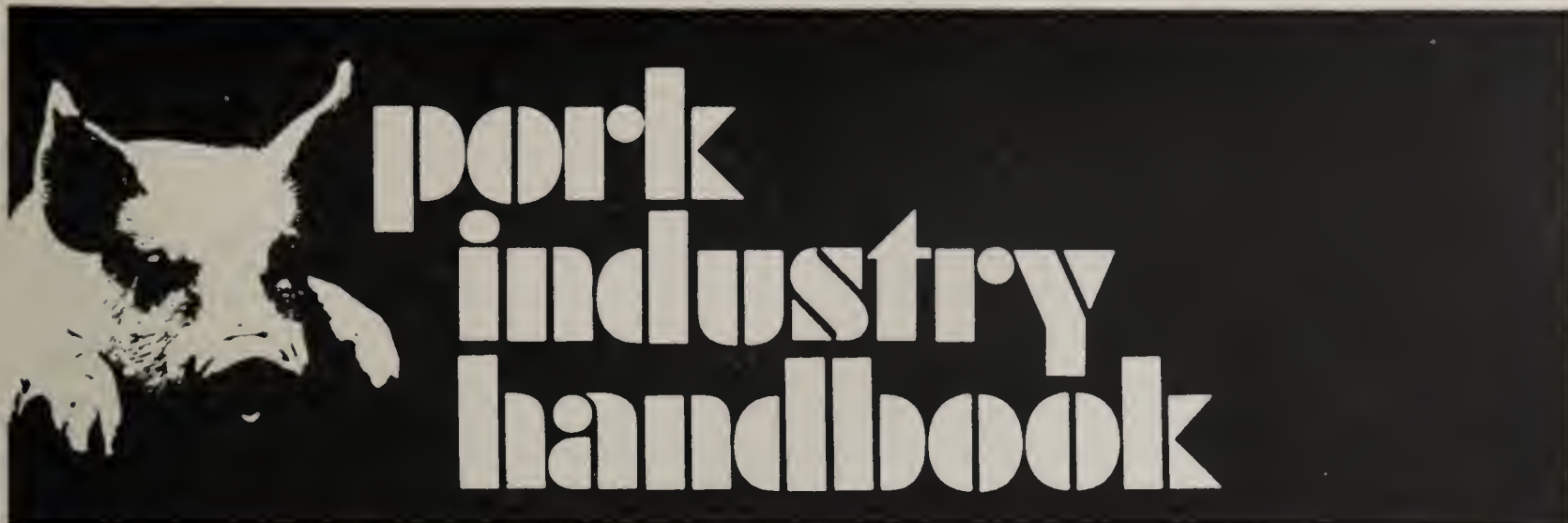
*Manure application rate can be expressed as (a) number of animals sold per acre per year or (b) number of acres required per 1,000 animals sold per year.

Using our example and assuming 2.5 groups produced from the operation (Note: the number of groups must be increased or decreased, depending on the intensity of the operation).

(a) 1,500 growing-finishing hogs (building capacity) x 2.5 groups/year = 3,750 hogs sold/year.

3,750 hogs sold/year ÷ 96 acres (from 5.d.) = 39 hogs/acre/year.

(b) 96 acres ÷ 3,750 hogs sold/year = .0256 acres/hog sold x 1,000 hogs = 25.6 acres/1,000 hogs sold.



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Supplemental Heat For Swine

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During some phases of the pig's growth from birth to market or replacement herd and for some types of management systems, the pig's normal heat production is insufficient to maintain a productive air temperature within the building. Under such conditions, supplemental heat is needed. Supplemental heat is heat added to the swine building to supplement the normal heat production of the animal, thus maintaining a productive environment.

In some buildings, such as the farrowing house, supplemental heat is regularly used, and permanent types of heating systems, such as unit heaters or make-up (ventilation) air heaters, should be considered. On an occasional need basis, a temporary heater that could be moved into the building for several days or a week will get a producer through a cold spell or a partial load period.

Permanent Heating Systems Unit Heaters

A unit heater has all the components assembled into one container and needs only to be hung in the building and connected to a source of fuel and electricity. (See Fig. 1.) The basic unit heater consists of some type of fan, either propeller or centrifugal, and a heating element. Sometimes air intake filters, directional discharge louvers and vanes, automatic temperature controls and safety controls are included. Unit heaters are generally installed overhead and thus do not use valuable floor space in the swine building. Most unit heaters use 100% recirculated air.

Several types of heating elements are available for use with unit heaters. For swine buildings, however, probably the direct-and/or indirect-fired gas burners and electric heating elements are the most common. Another choice would be a hot water element, especially in a farrowing or nursery building where underfloor hot water heat will be or already is used.

Since most unit heaters use recirculated air, dust could be a problem, depending upon the management and

feeding systems used. If filtration of the circulated air is desired, a centrifugal blower would work better than a propeller fan against the higher static pressure caused by the filter.

The size and number of heaters needed depend upon the heat requirement and floor area of the particular swine building. As an example, a 26 ft. x 76 ft., 28-sow farrowing



Figure 1. The discharge side of a typical centrifugal fan unit heater. Heater is hung from the ceiling and placed near an outside wall.

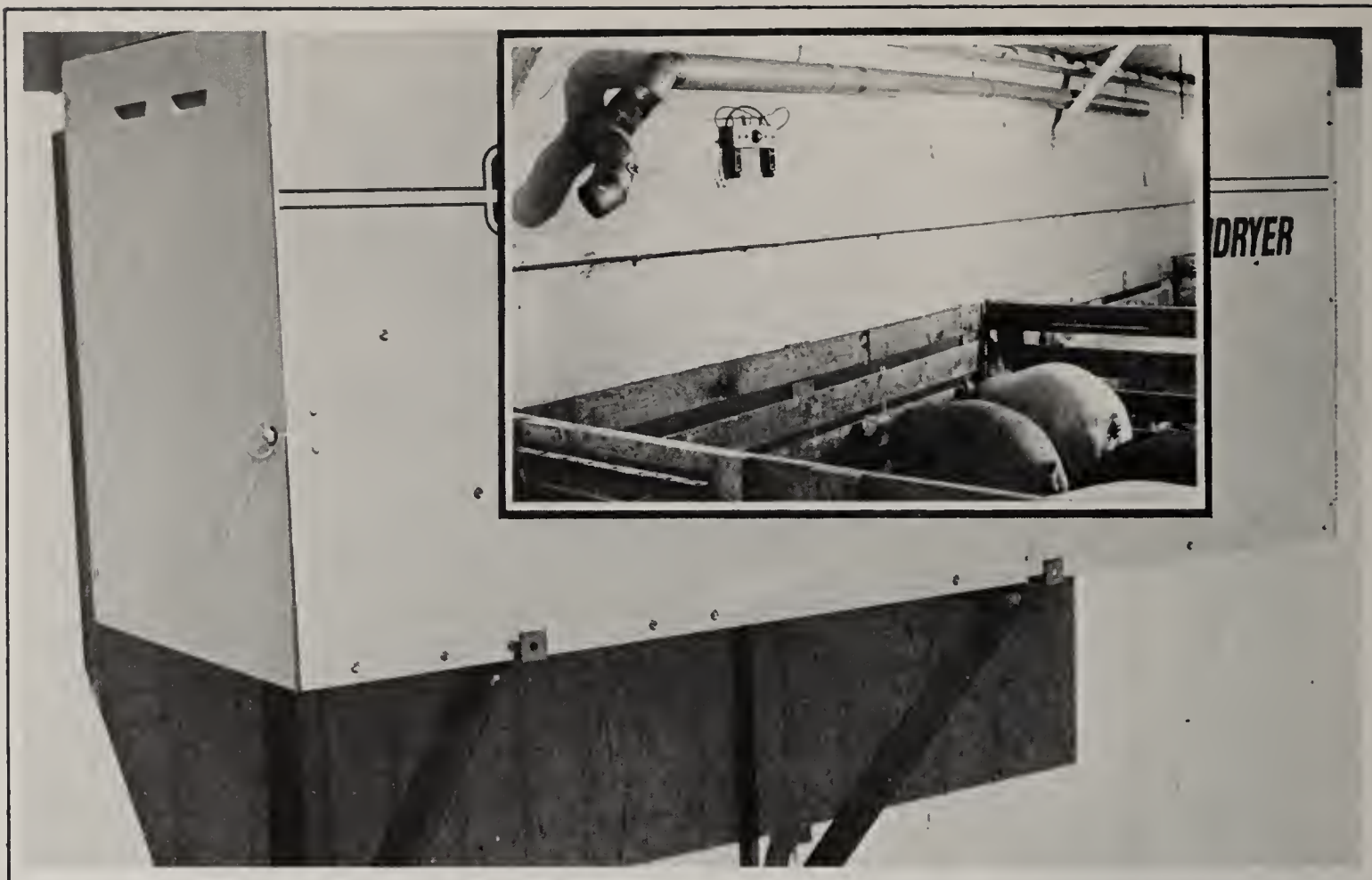


Figure 2. A direct-fired propane make-up air heater attached to the outside wall of a swine building. The insert shows the controls and a simple air distribution duct within the building.

house located in central Illinois indicated a need (when empty) of 35,000 BTU per hour of supplemental heat (R walls, 12; R ceiling, 15). The two smallest gas-fired, propeller fan unit heaters available from one manufacturer are 24 MBH (24,000 BTU per hour) and 40 MBH (40,000 BTU per hour) units. Thus, one 40 MBH or two 24 MBH unit heaters should be used. Electric unit heaters are available in smaller sizes than gas-fired. Small sizes of 2, 3, 4, 5 and 7.5 kW are generally available (6.8, 10.2, 13.6, 17.1 and 25.6 MBH).

The term blow (or throw) relates to the horizontal distance that the warm air is projected from the heater. In the previous example, since the 24 MBH and the 40 MBH unit heaters have about the same blow, the 40 MBH unit would not produce a uniform temperature throughout the house. Two 24 MBH heaters would do a better job of distributing the heated air, thus creating a more uniform inside temperature. Another choice for more uniform temperature would be a unit heater with a fan capable of operating at higher static pressures and some type of simple duct work or air tube to distribute the heated air along the length of the house. Perhaps better than the duct would be to divide the farrowing house into two smaller rooms with one 24 MBH heater per room.

More uniform inside conditions are obtained when the unit heater is installed to blow along the coldest wall. The warm air will intercept the cold drafts from that wall. Where several heaters are used, they should be so arranged that the discharge from each helps create a general circulatory motion of air within the building. Ceiling-mounted units with the outlet louvers properly set should deliver the heated air to the occupied zone (pig level) at temperature and velocities which are not objectionable.

Because of the potential dust and high humidity atmosphere, a regular maintenance schedule must be established. In the beginning, weekly inspection for dust build-up should be made until a maintenance schedule

can be predicted for your particular operation. This will assure maximum economy of operation and maintenance of heating capacity. The heating elements, fan blades and output louvers can be kept clean for effective operation by periodic brushing or blowing with high-pressure air. Whenever the building is cleaned with a high-pressure water or steam cleaner, the heater, if so constructed, should also be cleaned. (Totally disconnect electric power before cleaning, and be sure no moisture remains in the electrical boxes before restoring the power.) The fan motor should be a totally enclosed motor. All electrical wiring and fuel line connections should be inspected annually.

Make-up Air Heaters

Whereas the unit heater uses 100% recirculated air, the make-up (ventilation) air heater most commonly used heats 100% outside air entering the conditioned space or building. Since the make-up air heater heats air entering the building (see Fig. 2), some air must also be exhausted or removed from the building. Make-up air heaters are generally located outside of the space or building they are heating.

Make-up air heaters are sized either by rate of air flow through the unit, by the maximum energy input to the heating element, or by both methods. Typical farm application sizes range from about 600 to 2,000 cfm. with gas as the usual fuel choice. They are generally equipped with some type of automatic modulating gas flow valve which permits a turn-down ratio of 10 to 20. Modulation of the fuel flow permits a rather constant exit air temperature from the heater as the entering air temperature fluctuates. Most heaters have a potential of 120-230F temperature rise for the air passing through the heater when the fuel flow is at a maximum value.

The most common heater used in agriculture applications is the direct-fired propane gas heater which burns the gas directly in the air stream entering the building. Thus, all the products of combustion enter the

building along with the heated air. This is why the unit must only be used in a ventilated building. Approximately 92% of the energy burned in these heaters is heat available for a temperature increase. Since the heater is the primary source of air inlet to the building during its time of operation, it should be mounted to exclude rain and be fitted with a screen to exclude birds, paper, and other foreign materials. It should also be located so that the cleanest possible air is available for use, i.e., high enough from the ground so that blowing dust will not create a problem and far enough from an air exhaust from any building.

Operation of these heaters during winter is either as a part of the ventilation system or as the total ventilation system. The partial ventilation consideration is normally applied when an exhaust fan system is used for the building. The total ventilation system is generally a pressurized system.

Air distribution within an exhaust-ventilated building is greatly affected by the type and location of the air inlet. When the make-up air heater is operational, most of the air will enter at one point instead of being uniformly distributed around the building. This could cause air temperatures within the building to become uneven. Since the centrifugal fans generally used on make-up air heaters are capable of operating against higher static pressures, some type of simple interior duct work (see insert, Fig. 2) would permit the heated air to enter the space at several locations, thus improving air distribution within the building and restoring temperature uniformity.

Controls

Careful consideration should be given to the safety controls of heating equipment. If gas is the fuel used, some type of gas and fan shut off is needed if ignition by the electrical igniter does not occur within approximately one minute. Also, some type of manual reset flame sensor is needed that will shut down the unit in case the gas supply is exhausted. A sail switch, one sensitive to the flow of air, will make sure that the blower is functioning or that air is passing through the unit before the ignition circuit is even activated. If for some reason air flow stops after activation, the main gas valve should close. There should also be a high temperature switch to shut down the unit if the temperature at the discharge and/or at the burner becomes too great. The usual electrical safety equipment, such as circuit breakers, should be available to protect the blower motor from possible overload damage.

During the time when supplemental heaters are used, the ventilation system and the heaters are performing opposing tasks. The ventilation system provides a means to cool the building while heaters obviously provide heat for

the building. If both systems operate simultaneously, energy use will increase drastically and neither of the intended purposes will be achieved.

A minimum level of ventilation must be maintained in a swine building; thus, there will always be some overlap with the heating system. The controls used should be set so that heating starts after the inside temperature has decreased below the minimum ventilation rate setting. When several persons are involved in a swine operation *only one* should have the responsibility of adjusting the thermostat.

Temporary Heating Methods

The greatest need for temporary heating generally occurs when a building is understocked, perhaps at the start or end of a farrowing or nursery cycle, or when there are only a few animals in a large pen. A sudden cold spell could also require some type of quick, temporary heat.

Move-In Heaters

Most heaters moved into a building for temporary heating are direct-fired gas or oil. These heaters have their own fuel supply in an accompanying tank; no flue is necessary; and only 115 volt power is needed for fan and control operation. (See Fig. 3.) Sizes are available from about 30 MBH to 100 MBH. The size on hand will seldom fit the exact task to which it will be put, but most available sizes could get an operator through an emergency period without disaster.

The operating thermostat is usually located at the unit which will cause greater temperature fluctuations within the building. It is also difficult to coordinate such a unit with the normal ventilation controls to keep the two from acting against each other. Any unit employed in an animal shelter should have some type of "flame-out" control that will automatically shut off the fuel supply if the flame goes out for any reason. Loss of electrical power should cause a full shut down of the burner.

Radiant Heaters

Radiant heaters could be discussed either with temporary heating methods or with permanent systems. They have the special advantage that because heat is transmitted by radiation, like light rays rather than air heating, they can be used in open front buildings. The most common energy source is either gas (see Fig. 4) or electric.

Radiant heat is converted to normal heat when it strikes an object in its path. Thus, radiant heat shining on a pig is converted to heat, and the animal is comfortable even though the surrounding air, by itself, is too cool for comfort. Comfort can be provided without heating all the building air. This permits establishment of a dual environment in a farrowing house where the thermostat is set to maintain a



Figure 3. Temporary-type portable heater using fuel oil as the energy source. Blower and controls connect to 115 volt outlet.

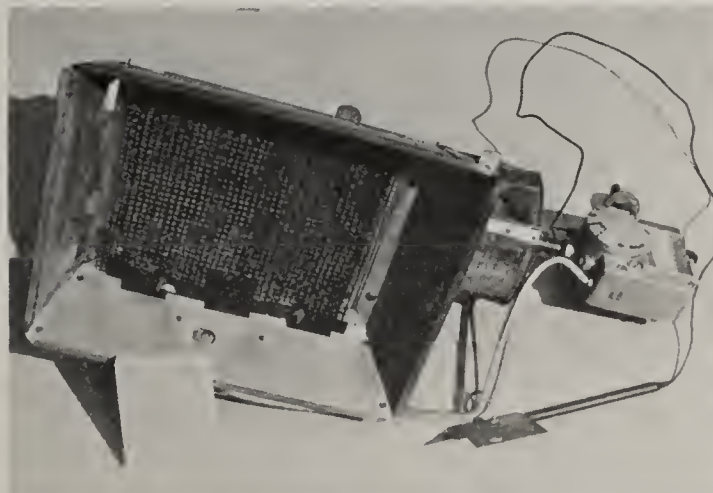


Figure 4. Underside of large gas-fired ceramic core radiant heater. Temperature control and automatic gas shut-off attached on right. Sample piece of perforated ceramic core element shown in foreground.

60F value, best for the sows, and radiant heat is added to the pig creeps to provide an 80-85F equivalent environment for the small pigs, the best for them.

Tests at Purdue University have shown that for nursery-aged pigs housed at 40F, average daily gains equivalent to that achieved at 70F can be obtained if 120 BTU per hour of radiant heat, measured at the pig level rather than energy input to the heater, is provided for each square foot of sleeping area. Radiant heat in an open front building could also replace the need for bedding or underfloor heat. A good indication of achievement of the desired thermal environment is obtained by visual signs of pig comfort. Additional suggestions for use of radiant heaters are shown in Table 1.

Creep area heating requires a localized high temperature source which is generally supplied by electrical heat lamps or gas-fired radiant heaters. (See Fig. 5.) Heat used in the creep area is ultimately added to the building and reduces space heating requirements. Space heating, as discussed earlier, can be accomplished with any of the fuels listed in Table 2. Efficiency of converting the fuel energy to heat depends on whether the heater is direct- or indirect-fired and on the fuel used. More of the energy is added to the space with a direct-fired heater, but only clean burning fuels can be used and only in ventilated buildings where permitted by insurance or code regulations.

Fuel Selection

The choice of fuel used in swine buildings depends on availability, price and special requirements. The main sources of energy in most regions of the United States are

propane and electricity. The relative availability of different fuels may change in coming years, especially in local situations, so some thought should be given to long-term supplies before making final decisions about equipment.

Fuel costs appearing in Table 2 are for one million BTU of energy added to the space. Price of fuel varies in different regions. Actual cost should be used for comparisons. A calculation for cost per million BTU at the new price can be made by setting up a ratio like the following example. Assume the cost of fuel oil is 50¢ per gallon instead of 45¢ as used in the table. Then,

$$\begin{aligned} \text{my cost per million BTU} &= \text{my price per gal.} \times \frac{\text{Table 2 cost}}{\text{Table 2 price}} \\ &= 50¢ \text{ per gal.} \times \frac{\$3.88}{\$0.45} \\ &= \$4.31 \end{aligned}$$

The cost of operating electric heat lamps or non-controlled gas-fired radiant heaters in a farrowing house is easily determined on an hourly use basis because the rate of energy consumption is constant. A 250-watt heat lamp uses $\frac{1}{4}$ kWhr during each hour of use. If electricity cost 3¢ per kWhr, then the cost of operation is $\frac{3}{4}$ ¢ per hour or 18¢ per day. A 4,000 BTU per hour gas-fired radiant heater uses slightly over 1 gal. of propane per day and operating cost at 40¢ per gal. is about 1 $\frac{1}{2}$ ¢ per hour or 40¢ per day. Since 1 gas unit is normally used for 2 stalls, the operating cost is the same as for electricity.

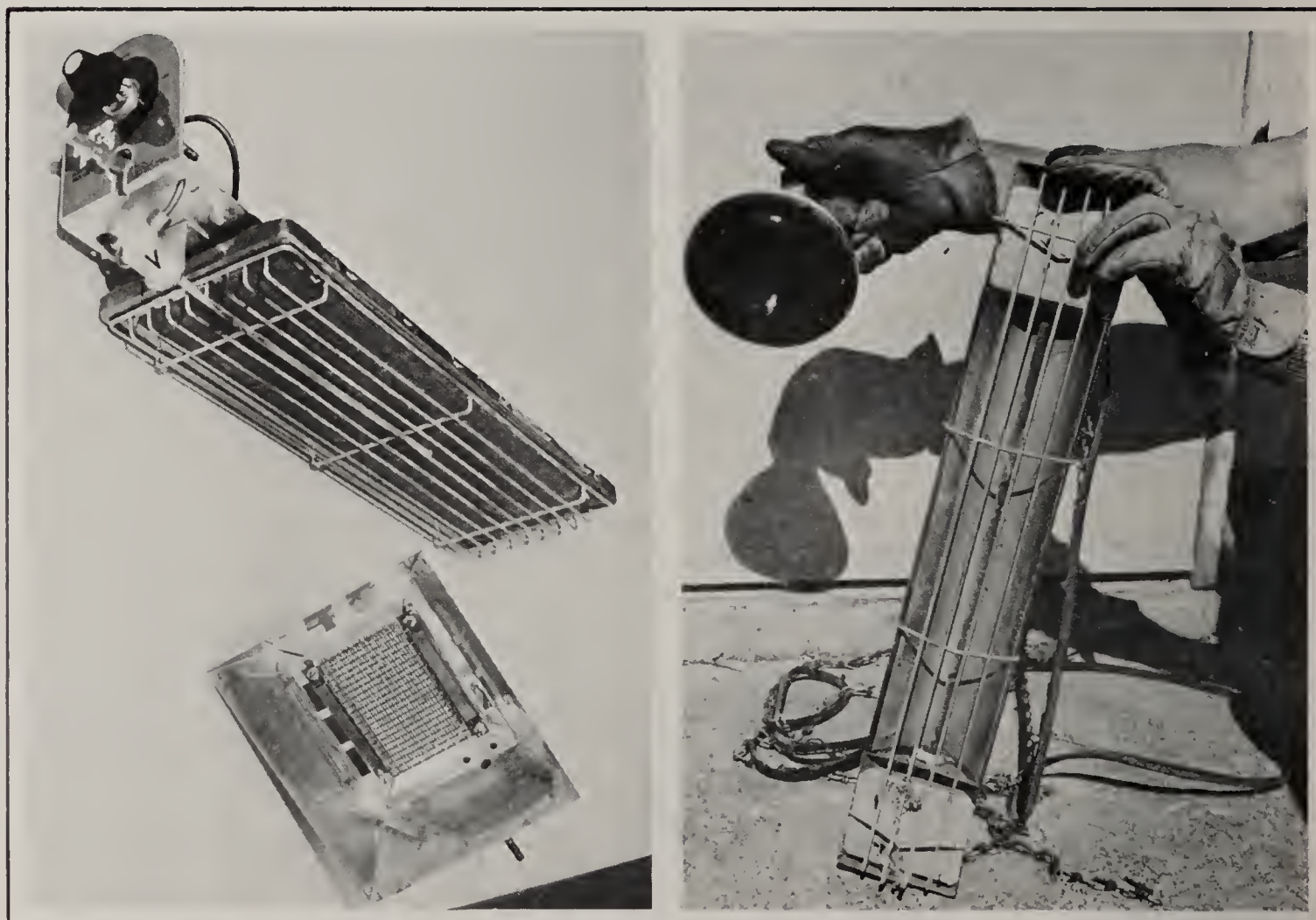


Figure 5. Four types of commonly used pig creep area heaters, gas-fired on the left and electrical on the right. Upper left is a catalytic burner having a temperature controlled gas valve and automatic shut-off. Lower left is a single element ceramic core burner, usually used uncontrolled. Held in the right hand is a common 250 watt reflector base infrared bulb. The left hand holds a short metal sheath infrared unit also operating on 115 volts.

Comparison of fuel cost for heating air to maintain inside temperature is illustrated by the following example. Assume that a 22-stall farrowing house typically takes 1500 gal. of propane per heating season, using an indirect-fired heater. What would be the cost per heating season and the amount that might be saved with a heater burning fuel oil? With propane at 40¢ per gal., total fuel cost for the year would be 1500 gal. $\times$ 40¢ per gal. = \$600. This \$600 for propane would purchase 110 million BTU. That is, $\$600 \div \5.45 per million BTU = 110 million BTU. Fuel oil at 45¢ per gal. to purchase 110 million BTU would cost 110 million BTU $\times$ \$3.88 per million BTU = \$427 and the reduction in fuel cost would be \$600 - \$427 = \$173.

Application Suggestions

Tables 3 and 4 show the supplemental heat requirements and the recommended systems for the four major groupings of swine. Location of the particular types of heaters was discussed earlier in detail.

Proper control of any heating system is necessary both from an economic standpoint and for safety. Thermostats for unit heaters and make-up air heaters should be hung low but still within easy visual range. They should be located so as not to be biased by the sun, animal mass, or by the output from nearby heaters. When using small radiant heaters, the operator generally assumes the task of the thermostat, turning them on and off as needed.

Table 1. Suggested use, location and control of radiant heaters for swine.

Type and Size	Use	Location and Number	Radiant Output	Control
Gas, Catalytic or Ceramic Core				
4-6 MBH*	Farrowing house	Hung over two adjacent pig creep areas	30-35%**	Uncontrolled: intentionally on or off.
10-12 MBH	Nursery and Growing/Finishing	5-6 ft. above the sleeping area; 1 heater per 100 ft ² of sleeping area	40-45%	Mounted air thermostat set at 35-40F in open front building, 50F in closed building. (Should have automatic gas shut-off in case of pilot light failure.)
Electric				
250 W bulb	Farrowing house	One per pig creep	70-75%	Uncontrolled: intentionally on or off.
1-2.5 kW	Nursery and Growing/Finishing	5-6 ft. above the sleeping area	75-80%	Radiant receptive thermostat advisable because of small amount of air heating. Settings similar to gas.
Gas or Electric	Emergency situations and partially loaded buildings	Near ceiling; as many as deemed necessary		Air thermostat set at 45-55F or manual adjustment as necessary.

*Thousand BTU per hour, input rating.

**30-45% of the input energy to gas heaters is given off as radiant heat. The remaining 50-65% of the energy heats the surrounding air. The radiant output of electrical heaters is higher than gas heaters.

Table 2. Representative cost for thermal energy from selected fuels used in heating applications. Typical efficiencies are used,* but equipment owning and maintenance cost is not included.

Energy Source	Heating Value	Typical Cost	Cost per Million BTU
1. Electricity			
a. Resistance Heating	3413 BTU per kWhr	3¢ per kWhr	\$8.79
b. Heat Pump (COP = 1.8)**	3413 BTU per kWhr	3¢ per kWhr	\$4.88
2. Fuel Oil	145,000 BTU per gal.	45¢ per gal.	\$3.88
3. Propane			
a. Direct Fired	91,700 BTU per gal.	40¢ per gal.	\$4.74
b. Indirect Fired	91,700 BTU per gal.	40¢ per gal.	\$5.45
4. Natural Gas			
a. Direct Fired	1,000 BTU per cu. ft.	22¢ per 100 cu. ft.	\$2.39
b. Indirect Fired	1,000 BTU per cu. ft.	22¢ per 100 cu. ft.	\$2.75

*Efficiencies assumed for the various units are: 100% for electricity; 92% for direct fired propane and natural gas; 80% for indirect fired propane, natural gas, and fuel oil.

**COP = coefficient of performance. The 1.8 means that for every kWhr of electrical input, there is 1.8 kWhr of heat output.

Table 3. Supplemental heat requirements for several groups of swine

Swine Group	Heater Size	Desired Temperature	Comments
Farrowing: Sow and litter	2 MBH* to 3 MBH per farrowing space plus creep heaters	60F, sows 80-85F, pigs	Premature or SPF pigs need 90-95F for first week. Pigs from 1 week to 3 or 4 weeks need 75-80F. No drafts. Conserve heat with insulation under creep area, straw bedding, carpeting etc.
Early weaned pigs, 3 to 4 weeks	¼ MBH per pig	80-85F	Early weaned (3 to 4 weeks) pigs need 80-85F continued for two weeks after which the temperature can be lowered gradually to 70-75F.
Weaning and/or nursery pigs: 5 weeks until 50-60 lb.	¼ MBH per pig	Sleeping area at 70-75F	Heat can be discontinued or reduced when pigs reach 6 to 8 weeks of age. If pigs are with sows, provide creep area at indicated temperature.
Growing/finishing up to 60 lb. 60-100 lb. 100-150 lb. 150 lb.--market	Generally not needed	70-75F 65-70F 60-65F 60F	May need some temporary heat to get started, during inclement weather or if building is only partially loaded.
Sow gestation and boar housing	None in corn belt and south	60F	Animals tolerate 40-80F. Provide dry, draft-free sleeping area.

*Thousand BTU per hour

Table 4. Recommended supplemental heat systems for several groups of swine.

Swine Group	Heated Area	Comments
Farrowing: Sow and litter	Room	To maintain minimum room temperature use unit or make-up air heaters.
	Pig Creep	Gas or electric radiant heaters; electrically heated pad on the floor; combination of pad and hover; some type of under floor heat.
Weaning and/or nursery pigs: 3-5 weeks until 50-60 lb.	Solid floor rooms	Similar to pig creep area in farrowing house. (If sows are in pen with pigs, locate heaters so that sows cannot tear them out or have access to them.)
	Totally slotted floor rooms	Use unit or make-up heaters to maintain room temperature.
	Partially slotted floor rooms	Use combination of above suggestions for solid floor and totally slotted floor rooms.
Growing/finishing, Sow gestation and boar housing	Enclosed, insulated building	Usually no heat required. Could use temporary heat during extremely cold weather or partial load periods. For more permanent heat installation, the make-up air heater would have less of a dust problem.
	Open front building	Opening should be on south or east side. Overhead radiant heat, either gas or electric used for sleeping area only. Bedding, a low ceiling, and solid pen sides in the sleeping area will help conserve pig heat and prevent drafts. A low ceiling is not compatible with overhead radiant heat.

All gas lines and/or gas heaters should have safety shut-off valves. If the gas supply is interrupted, all valves should close and require manual resetting unless automatic electric ignition is provided for the heater. Small gas radiant heaters usually do not have pilot lights and safety shut-off valves and thus need to be closely monitored by a reliable operator.

Electrical wiring in and to the swine buildings must be of adequate size if electrical supplemental heaters are to be used. Circuit load capacity is determined by the wire size

used and not by the size of the fuse that could be placed in the fuse box. Any changes made in the electrical system should be done by someone capable of determining safe circuit loads.

Reference to products in this publication is not intended to be an endorsement to the exclusion of others which may be similar. Persons using such products assume responsibility for their use in accordance with current directions of the manufacturer.



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Economics of Reproductive Performance and Breeding Herd Management

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During the summer of 1977 it was costing about \$29 to produce a 40-lb. feeder pig if one did not deduct the salvage value of breeding stock and tax savings on breeding stock sales. This production cost can be achieved with feed costs of 6-7 cents per pound and with the use of modern facilities and equipment if one can obtain 1.7 litters per female in the herd and 8.0 pigs weaned per litter. While these production goals are higher than the national average of 1.5 and 7.3, respectively, they are realistic.

These figures can be determined for your herd by dividing the total number of pigs weaned per year by the number of farrowings during the year; and by dividing the total number of farrowings that occurred during the year by the average number of females in the herd. The average number of females in the herd is determined from monthly inventories, and gilts are included in the inventories from the time they are 6 months of age. The accompanying Monthly Breeding Stock and Production Inventory Record will be helpful in measuring your herd's performance.

Salvage Value of Breeding Stock

About 50% of the costs of producing a 40-lb. feeder pig are feed costs. Most of this is feed cost for the breeding herd. However, some of this feed cost is recovered in weight gain, since the sow enters the herd as a 220-lb. replacement gilt and accumulates 150-300 lb. additional weight during her productive lifetime. Admittedly, some sows die, and the salvage value per pound decreases as the sow gains in weight; but nonetheless, salvage value of the home-raised breeding stock reduces the net cost to produce a weaned pig.

A gilt normally gains more weight during gestation than a sow because she is still growing. Thus, the cost of producing pigs out of gilts is not as high as it would appear to be based on the number of days in the breeding herd and the litter size produced. Studies indicate that gilts are in the

herd about 270 days by the time they wean their first litter, and that they wean about 6.6 pigs per litter. Sows average 208 days in the herd, per litter produced, and wean about 7.9 pigs per litter during their second and subsequent litters.

Depending on market prices, gilts increase in value by \$25-75 from the time of their selection as 220-lb. replacement gilts until they are sold as packers at weights of 350-500 lb. This \$25-75 value increase can be considered either additional income or can be used to defray the cost of producing weaned pigs. Dividing the value of the increase by the number of pigs produced during the sow's lifetime gives the value on a per pig basis. Since most of the increase in value occurs during the first litter and since the number of pigs per litter is usually less than 7, the value per pig is considerably higher (\$3-5 per pig) than it is for pigs from sows that are kept for as many as 4 litters and produce more than 30 pigs.

Tax Savings

Using the cash basis for reporting income, our federal tax system allows a producer to pay a much lower rate of federal income tax on the income from the sale of raised swine breeding stock which is held 12 months or more. This item markedly influences the after-tax cost of producing feeder pigs and tends to encourage producers who are in the higher income tax brackets to maintain young breeding herds.

Income from the sale of breeding stock for a 1-litter system and for a 4-litter system can differ considerably, as shown in Table 1.

Adding to this tax saving advantage of the 1-litter system is the added tax paid on the profit from the sale of 6.9 additional pigs with the 4-litter system.

The net effect of the increase in salvage value and tax savings at the above production rates and prices is about \$7.50 per pig advantage for the 1-litter system. This

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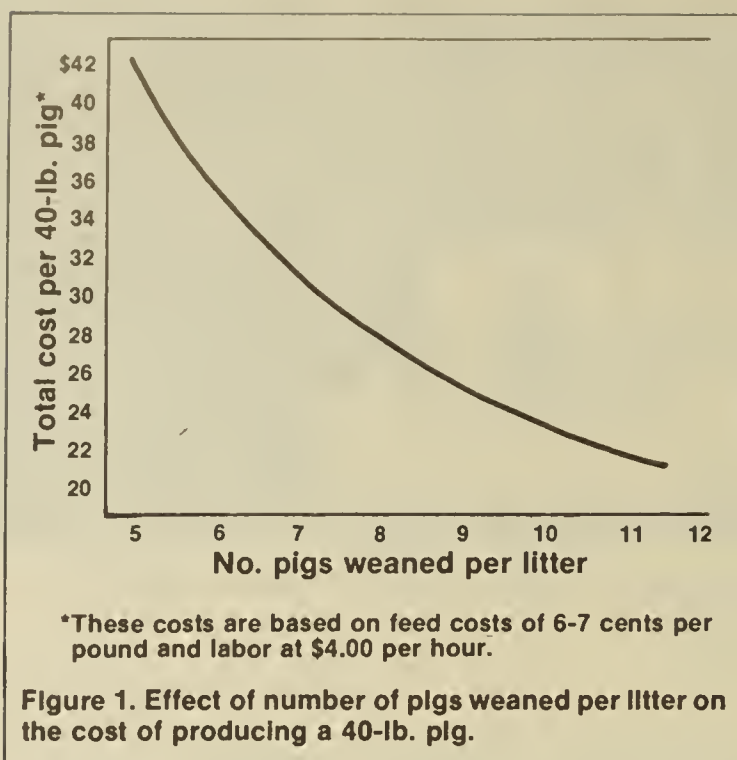


Table 1. Tax considerations of 1-litter system as compared to 4-litter system.

	1-litter system	4-litter system
No. litters	4.00	4.00
No. pigs weaned	26.40	30.30
No. pigs sold	22.40	29.30
Value of sow sales	\$575.00	\$160.00
Amount not taxable	\$287.50	\$ 80.00
Tax savings		
25% tax bracket	\$ 71.88	\$ 20.00
Tax savings/litter	\$ 17.97	\$ 5.00
Tax savings/pig		
25% bracket	\$ 2.72	\$ 0.66

amount can be used to offset the higher feed and production costs of the 1-litter system.

Reduce Feed Costs

There are two ways to reduce sow feed costs per pig even when sows are fed properly. First, wean more pigs per litter and, second, produce more litters (and total pigs) per sow per year. The feed savings from weaning more pigs per litter are rather obvious. It doesn't take any more feed during gestation to feed a sow carrying a larger litter than it does to feed one carrying a small litter. Likewise, it doesn't take much more feed for a sow nursing a large litter as compared to a small litter.

Wean More Pigs per Litter

Some of the other production costs per pig are also reduced as the number of pigs weaned per litter is increased. Facilities, labor, interest on capital, power, fuel, electrical and medical expenses—all are lower per pig when the total costs can be shared by more pigs.

Figure 1 shows the effect of number weaned per litter on total production costs.

The costs shown in Figure 1 are based on 1.7 litters per sow per year. Costs of production are reduced \$2-5 per pig for each additional pig that can be weaned per litter. Weaning 9 instead of 8 reduced production costs by \$2.35 per pig.

A number of practices have been reported to be useful in increasing the number of pigs weaned per litter. Refer to the PIH Fact Sheets listed at the end of this publication.

More Litters per Year

Farrowing more litters per year from each female is another method of reducing production costs per pig. Our inability to shorten the gestation period limits the amount of improvement we can expect to make in this area. The gestation period is only 114 days, and yet most of our pork producers are allowing over 215 days per litter ($365 \div 1.7$ litters = 215). Under optimal conditions, one could expect a second-litter sow to take 114 days for gestation, 21-28 days for lactation and 6 days to return to estrus. This would give a total of 141-148 days per litter. This level is sometimes achieved by individual sows in a herd but is not obtained on a herd basis. The proportion of gilts in the breeding herd, the number of non-breeders, and conception rates of only 70-80% add to the total female days per litter farrowed. Nevertheless, improvements can be made and savings in production costs can be noted.

Increasing the number of litters per sow per year reduces the sow feed costs for non-gestating periods or for a given number of pigs, and it reduces both the size of the breeding herd and the gestating sow facilities required (see Table 2). Gilts enter the breeding herd when they are 6 months of age, and with the addition of a high percentage of gilts the number of litters per female per year is reduced because:

- Gilts are usually not exposed for breeding until they are 7-8 months of age.
- It takes 21 days for them to be exposed to a first service.
- Animals not showing heat and non-conceiving animals are often not culled until they have been in residence for a large number of days.
- Gilt herds usually have lower conception rates than sow herds, especially when the breeding herd is in total confinement.

Therefore, herds that achieve a high number of litters per female per year usually have experienced higher conception rates and have a higher percentage of mature sows.

Table 3 illustrates the effect of increased litters per female per year on production costs. But it omits the reduction in costs associated with salvage value of the sow and capital gains income tax benefits where the lower litters per female per year is due to an increase in proportion of gilt farrowings.

If one plans and designs a given capacity in gestation and farrowing facilities and equipment for a productivity of 1.7 litters per year, holds the size of the breeding herd constant, and then experiences only 1.3, the results can be considerably different (see Table 4).

In addition to building costs, other costs per pig will also be higher. These include higher feed costs, higher boar costs, higher capital costs, higher fuel and power costs, and either higher labor costs or poorer utilization of the labor that is available.

Many management practices can be utilized to improve the number of litters produced per female per year. The following practices can be helpful.

Increasing Profits in the Breeding Herd

- Identify each sow in the herd.
- Keep records of breeding dates and boars used.
- Shorten lactation periods to 3 weeks.
- Breed at first heat after weaning.
- Cull non-breeders after 2 heat cycles.
- Pregnancy test non-cycling animals.
- Breed twice at each heat period.

There are still other related management problems that may affect or modify the assumed goal of achieving high reproductive efficiency. The management techniques that

Table 2. Yearly sow herd size per 100 farrowings with varying numbers of litters per sow per year.

Litters/sow/year	Average no. sows
1.2	83
1.3	77
1.4	71
1.5	67
1.6	62
1.7	59
1.8	56
1.9	53
2.0	50

Table 3. Effect of the number of litters per female per year on cost of producing pigs.

No. litters/ female/year	Cost of 40-lb. pigs
1.4	\$31.00
1.6	30.00
1.8	28.50
2.0	28.00

These costs are based on feed costs of 6-7 cents per pound and labor at \$4.00 per hour. They are also based on 8 pigs weaned per litter. It is assumed that when the number of litters per sow per year is reduced the size of the breeding herd is increased so that the herd farrows the same number of litters per year.

Monthly Breeding Stock and Production Inventory Record (1)

Year 19__

Column	1	2	3	4	5	6
	No. sows (2)	No. gilts (3)	No. sows and gilts farrowed	No. live pigs farrowed	No. litters weaned	No. pigs weaned
Jan.						
Feb.						
Mar.						
Apr.						
May						
June						
July						
Aug.						
Sept.						
Oct.						
Nov.						
Dec.						
Total						

- (1) Enter these data on the last day of each month.
- (2) Replacements are counted as gilts until they wean their first litter.
- (3) Gilts are counted in the breeding herd when they are selected out of the finishing lot.

Complete the information below at the end of the year.

- A. Column 1 ____ + column 2 ____ ÷ 12 = average sow herd size
- B. Column 5 total ____ ÷ average sow herd size ____ = litters per sow per year ____
- C. Column 6 total ____ ÷ average sow herd size ____ = pigs weaned per sow per year ____

will give a measure of control over many of these problems are not yet well defined. The accompanying Breeding Herd Efficiency Worksheet can help you determine your variable costs per pig weaned. It is designed so that you can use production figures from your own experience.

Additional information on improving reproductive efficiency can be found in the following PIH Fact Sheets.

PIH-1 Management of the Boar
 PIH-8 Managing Sows and Gilts During Breeding and Gestation for Efficient Reproduction
 PIH-18 Baby Pig Management—Birth to Weaning
 PIH-46 Care of the Sow During Farrowing and Lactation

Table 4. Effect of reproductive performance and building costs on cost per pig produced.

Percent capacity	100%		75%	
Litters/sow/year	1.7		1.3	
Number weaned/litter	9	7	9	7
Farrowing				
\$1,000/sow capacity	\$3.50	\$4.50	\$4.69	\$6.03
Nursery				
\$42/pig capacity	1.25	1.43	1.48	1.90
Gestation				
\$200/sow capacity	2.00	2.57	2.61	3.36
Total	\$6.75	\$8.50	\$8.78	\$11.29

Breeding Herd Efficiency Worksheet

I. Total cost per farrowing:

A. Feed and time related costs*

	Gilt system	Gilt & sow system
1. Lactation _____ days × \$_____ per day =	\$_____	\$_____
2. Gestation <u>114</u> days × \$_____ per day =	\$_____	\$_____
3. Breeding days and boar cost <u>25</u> days × \$_____ per day =	\$_____	\$_____
4. Prebreeding and culling† _____ days × \$_____ per day =	\$_____	\$_____
5. Cost per farrowing	\$_____	\$_____

B. Gain in salvage value

	Gilt	Sow
1. Salvage value (weight × price) =	_____	_____
2. Cost of female (220 lb. × price) =	_____	_____
3. Net cost (line 1 - line 2)	_____	_____
4. No. of farrowings <u>1</u>	_____	_____
5. Net cost/farrowing (line 3 ÷ line 4)	\$_____	\$_____

C. Income tax savings (raised breeding stock)

1. Salvage value (weight × price) =	_____	_____
2. Number of farrowings <u>1</u>	_____	_____
3. Salvage value per farrowing	_____	_____
4. Tax bracket _____ % ÷ 2 × line 3 =	\$_____	\$_____

D. Total cost/farrowing (line A5 - line B5 - line C4) = \$_____

II. Average number of pigs weaned during breeding life:

A. 1st litter _____ pigs weaned.		
B. 2nd litter _____ pigs weaned.		
C. 3rd litter _____ pigs weaned.		
D. 4th litter _____ pigs weaned.		
E. 5th litter _____ pigs weaned.		
F. Total _____ pigs weaned.		
G. Average number weaned per farrowing	_____	_____

III. Average variable cost per pig weaned:

Total cost per farrowing (ID) divided by the average number of pigs weaned per litter (IIG) equals the variable cost per pig weaned.	\$_____	\$_____
	\$_____	\$_____

The following values can be used if actual values are not available:

* Cost of feed × 2 for lactation and breeding charges. Feed cost plus 30% for gestation, prebreeding and culling days.

† Prebreeding and culling days:

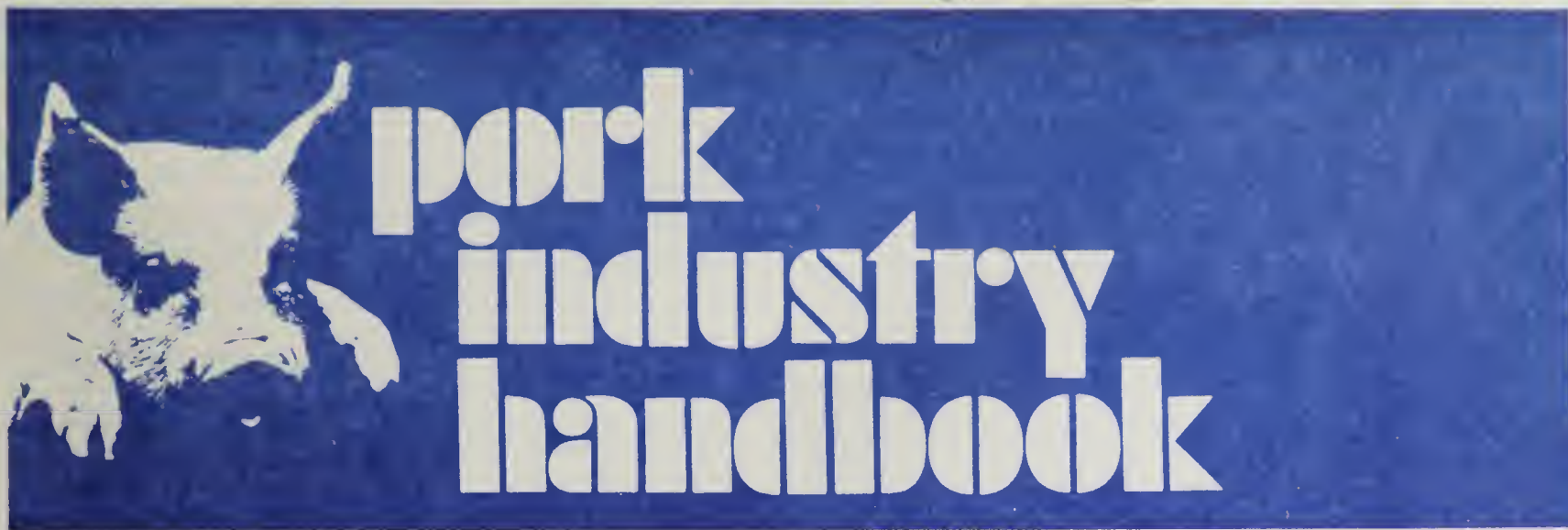
Gilts 100 days/litter

1 gilt litter, 1 sow litter = 69 days/litter

1 gilt litter, 2 sow litters = 58 days/litter

1 gilt litter, 3 sow litters = 53 days/litter

1 gilt litter, 4 sow litters = 50 days/litter



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Care of the Sow during Farrowing and Lactation

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Introduction

Proper care of the sow during gestation, farrowing, and lactation is a means to reach a goal—a large litter of healthy pigs at birth that will remain healthy and grow rapidly. Care during this time must also prepare the sow for a successful repeat performance at the earliest time within the system of weaning and rebreeding used. The sow must reach farrowing in the best nutritional and microbiological health for herself and for the expected litter. Properly balanced rations should be fed in recommended amounts so that newborn pigs are well developed and strong. A herd health program that assures minimal exposure of the sow to disease or disease carriers during gestation is essential for maximal litter survival during the first weeks of life and for effective growth to weaning and market. The sows should be managed in a gentle and confident manner and on a regular daily schedule.

Pre-farrowing Deworming Sows

Sows should be dewormed about two weeks before moving to farrowing crates or pens. Treatment for external parasites at least twice (in approved repeat times for the product used) also should be accomplished within a few days before movement to the farrowing facility. (See PIH-44).

Prepare the Farrowing Units

If possible, the total farrowing unit should be cleaned completely of organic matter, disinfected and left unused for 5-7 days before a new group of sows is placed in the unit. When this is not practical, at least the individual pen, stall or crate should be completely cleaned of organic matter and disinfected before a new sow is placed in the unit.

"Clean" means what it says. The floors, partition walls, ceilings and equipment should have *all* organic matter, including dust, removed. This can be accomplished by



scraping, use of high pressure cleaners, steam cleaners, and/or a stiff scrub brush. Do a complete job.

Disinfectants are useless unless the cleaning job is complete. But there are many good disinfectants available, including the quaternary ammonium compounds, iodoform

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compounds and others such as lye, to use when the cleaning job is done well. Some disinfectants such as those that contain coal tars or lye should be thoroughly rinsed off after several hours, especially from surfaces having direct contact with pigs.

Washing the Sow

Before the sow is placed in the farrowing pen, wash the teats and belly with mild soap and warm water. This will eliminate soil and fecal material that may contain numerous bacteria that are potential diarrhea-producing agents for the nursing pigs. This procedure will also eliminate ascaris (round worm) eggs that would serve as a source of infection to the nursing pig.

Feeding the Sow

During pre-farrow in the facility, sows can be fed as they have been during gestation. Better results are often reported, however, from feeding a laxative ration to prevent constipation. Constipation can be prevented or corrected by changing to a bland or bulky diet, by addition of 20 lb./ton of epsom salts or 15 lb./ton of potassium chloride, by use of linseed meal as part of the protein in the ration, or by use of other laxative ingredients. Oats or wheat bran may be used as 25% of the grain to create a bulky ration; in some areas, other fibrous feeds such as alfalfa meal or beet pulp may be preferred. Water should be freely available, but spillage that could cause wetness of the pen should be prevented.

Farrowing and Lactation Temperature Requirements

Temperature in the sow area should be in the sow comfort range of 55-75 F.; on solid or slotted floors without bedding, baby pig areas should be kept at 90 -95 F. for the first few days, and then in the 70-80 F. range until weaning at 3-6 weeks of age.

Knowing When a Sow Will Farrow

The sow must be at the right place at the right time for farrowing, according to the management system used. Recorded breeding dates, calculated farrowing dates, and close observation are essential for proper farrowing management. Signs during late pregnancy help to insure that sows do not farrow at the wrong place and without proper attention.

If farrowing is to take place in a crate or pen, the sow should be in that place no later than the 110th day of gestation. This avoids loss of litters farrowed on the short end of a normal gestation period (111-115 days) and permits time for dams to become accustomed to the facility and routine of daily care before onset of birth. If breeding dates are not recorded, each sow should be carefully observed daily during obvious late pregnancy for enlarged abdomen area, swollen vulva, and filled teats as basis for estimating the farrowing date.

Presence of milk usually indicates that farrowing will occur within 24 hours. The milk may be grayish in its earliest stage but becomes characteristically white as time of farrowing approaches. Sows may become restless or nervous, may try to escape the crate, chew on anything available, urinate frequently, and attempt to build a nest or bed.

If milk is present, the sow should be prepared and moved immediately to the farrowing facility. If farrowing facility space is available, move questionable sows to the facility early rather than waiting "one more day."

The Birth Process

Attending sows at farrowing decreases the number of "stillborn" pigs that die during birth or within the first few hours afterwards; pigs can be freed from membranes, weak pigs revived, etc., and care can be given that reduces other deaths in the first few days after farrowing.

Duration of labor ranges from 30 minutes to more than 5 hours. Pigs may be born either head first or rear feet first; either is normal. Some fetal membrane may partially cover pigs, but afterbirth generally occurs in a larger amount near the end of farrowing. Occasionally, a pig is enclosed in the afterbirth material and will quickly suffocate if not removed from it. "Stillborn" pigs are those that have died during farrowing; dead pigs may have been dead for only a few days or for an extended time; "mummies" are pigs that have been dead long enough for much reabsorption of the soft tissues, but not of the skeleton, to have taken place.

The average interval between birth of pigs is approximately 15 minutes but can vary from simultaneous to several hours in individual cases. Use of oxytocin to speed up rate of delivery is useful if correctly done and if farrowing is proceeding slowly but otherwise normally. A rule of thumb, not universally recommended but widely followed, is to administer oxytocin when the first interval of 30 minutes after birth of the previous pigs has occurred without birth of another pig or without expelling membranes that indicate farrowing is completed. Oxytocin should not be used until birth of one or more pigs has occurred. Oxytocin should *not* be used if symptoms, such as straining without delivery, indicate that a pig is blocking the birth canal.

Prolonged labor, especially that which is associated with difficult birth, and litters produced by large, older sows, are often accompanied by increased numbers of stillbirths and added death losses in the first few days after farrowing. Sows that have been overfed during gestation are more subject to prolonged labor, and some individuals seem to be genetically prone to this problem. Proper feeding can prevent overweight, and selection and culling may eliminate animals that are generally prone to difficult births.

Assisting Difficult Births

At times, manual assistance is necessary to accomplish delivery but should not be used until obviously needed. Continued strong labor for an extended period without birth of pigs indicates need for such assistance. A well-lubricated, gloved hand and arm should be inserted into the reproductive tract as far as needed to encounter a pig "in place" for birth; the pig should be grasped and gently but firmly pulled to assist delivery.

Difficult births often enhance the occurrence of symptoms of MMA—mastitis (inflammation of the udder), metritis (inflammation of the uterus), agalactia (inadequate milk supply) (See PIH-37). To decrease the likelihood of creating complications as a result of manual assistance, use an antibacterial solution, such as nitrofurazone, as a lubricant for this purpose. Infusion of 50-100 cc. of such solution into the reproductive tract following conclusion of farrowing often helps decrease or prevent infection. Intramuscular injection with an antibiotic can also be helpful.

Nervous and Hysterical Sows

Some sows may become temporarily "hysterical" and vicious; these are likely to trample or lie on several of their pigs or kill them by biting; some producers cull these sows on temperament. Such sows must be attended to prevent

loss of newborn pigs; loss can be prevented or minimized by removing pigs to a warm place until farrowing is completed. The hysteria generally subsides in a few hours. Test the sow by placing only one pig with her and watching her reaction.

Nutrition of Newborn Pigs

It is highly important that each pig receive colostrum to provide immediate and temporary protection against common bacterial infections. Pigs are born into a hostile bacterial environment. Antibodies in the sow's milk are the best protection against these bacteria. Proper nutrition of the sow, including a laxative ration prior to and following farrowing; maintaining proper environmental temperature; and freedom from contagious disease organisms—all help to insure normal milk production.

Baby pigs may be unable to nurse because of a hostile sow, a large litter of pigs, small or otherwise weak pigs, death of the sow, or failure of the sow to have milk. Other ways baby pigs can get antibodies are by being bottle-fed colostrum; they can foster-nurse another newly farrowed sow; or they can nurse a sow whose litter is well beyond the 3-day-old stage frequently considered as the upper limit for transferring pigs. Colostrum can be hand-milked to provide initial artificial feedings; prolonged needs may be met by rotating pigs to other dams whose litters are removed for an hour or two, or by a permanent transfer to a foster dam. Gentle sows with litters as old as 3 weeks can be used as foster mothers for newborn pigs; it is good insurance to feed some colostrum before transfer to such a sow.

Sow milk replacers are nutritionally adequate for newborn pigs, but they lack antibodies; they do contain antibiotics, which help to control growth of unfavorable bacteria. Effective use of sow milk replacers requires stringent cleanliness of feeding equipment and housing area for baby pigs to control bacterial growth. Diarrhea is a common hazard for newborn pigs reared artificially in make-shift conditions. Wetness, chilling, and engorgement promote diarrhea.

Feeding the Sow during Lactation

Sows need not be fed for 12-24 hours after farrowing, but water should be continuously available. Two or three lb. of a laxative feed may be fed at the first post-farrow feeding; amount fed should be gradually increased until the maximal feed level is reached by 10 days after farrowing. Full feeding from the day of farrowing can be successfully used. Sows that are thin at farrow may benefit from generous feeding in the early post-farrow.

Sows nursing large litters need essentially full feeding during lactation. This may depend somewhat on the energy content of the ration and the length of the lactation period if sows are mated at first post-weaning estrus. In sows that finish lactation with excessive weight losses and in an energy-depleted condition, estrus tends to be delayed well beyond the usual 3-7 days post-weaning.

Experiments are underway to re-evaluate what constitutes the most economical lactation feeding programs. Sows in normal condition at farrowing can lose weight during lactation without impairment of pig growth or loss of breeding efficiency. Sows nursing fewer than 8 pigs may be fed a basic maintenance amount (6 lb./day) with an added allotment, such as 0.5 lb. for each pig being nursed. It is not necessary to reduce feed intake before weaning. Regardless of level of feed intake, milk secretion in an udder will cease when pressure reaches a certain threshold level.

Feeding the Pig during Lactation

Sows' milk does not contain enough iron for baby pigs. Iron must be given to pigs within their first 3 or 4 days or anemia will result.

Pigs can be supplied with iron by giving them clean sod (not from a hog lot), iron injections (iron dextran in the ham or heavy neck muscle), or iron compounds mixed with other minerals which pigs can eat. (See PIH-34.)

When pigs are about 1 week old, start feeding them a prestarter (about 20% protein) or starter feed in a shallow pan. The prestarter is usually more acceptable and pigs will start to eat earlier. It is used only to get pigs to start to eat. A little prestarter or starter feed mixed with some clean sod will often start pigs eating earlier.

After pigs start to eat, switch to a starter feed (about 18% protein) and feed this until the pigs weigh 25-30 lb. At this time, the ration can be switched to a lower cost (16%) pig grower feed.

Clean, fresh water should be available to pigs even before they start to eat dry feeds.

Controlling Health Problems

Sows should be observed carefully during the first few days after farrowing. Lack of appetite, listlessness, and failure to respond positively to nursing activity of the pigs indicate need for corrective treatment. Prevention of these conditions will decrease incidence and severity of the MMA syndrome. (See PIH-37.)

If MMA is prevalent, a prevention and treatment program should be developed through veterinary consultation and by management programs. The same is true for diseases such as atrophic rhinitis, transmissible gastroenteritis, Smedi, and mycoplasmal pneumonia. Checking for normal bowel activity and use of a rectal thermometer to detect fever can pinpoint early need for treatment.

Disease Prevention

Despite recent advances in the diagnosis and preventive procedures for the control of some diseases, the sow and her newborn litter remain vulnerable to a substantial number of pathogenic agents. Most successful producers plan their management programs to circumvent as much as possible disease transmission during this critical time. Maximum isolation of the pregnant sow and gilt from all rodents, cats, dogs, humans and new herd additions is a productive practice. Likewise, careful cleaning and sanitizing of facilities as described is important. Thorough cleansing of the sow as she enters the farrowing facility seemingly has been a factor in controlling some contagious disease organisms. Managing the sow and litter to insure maximal colostrum intake has distinct advantage for the newborn litter.

If swine are being reared in areas of heavy swine concentrations, vaccines and bacterins should be used to the fullest advantage. This is particularly true during seasons of the year when stress is unavoidable and when the viability of pathogens is high. Examples of diseases for which immunization seems wise are transmissible gastroenteritis (TGE) (See PIH-47), erysipelas, leptospirosis (5 strains), and in some localities perhaps pseudorabies. A federally licensed and approved vaccine is now available for use in the prevention of atrophic rhinitis (See PIH-50). The large number of enteric disorders that pose a threat to the newborn are perhaps best prevented by eliminating stressors such as cold and drafty pig areas, high humidity and unsanitary surroundings within the house. Some herds

are now receiving autogenous types of bacterins in situations where enteric problems are extreme.

The old axiom that an ounce of prevention is worth a pound of cure seems particularly applicable to this stage of the life cycle.

Schedule of Events

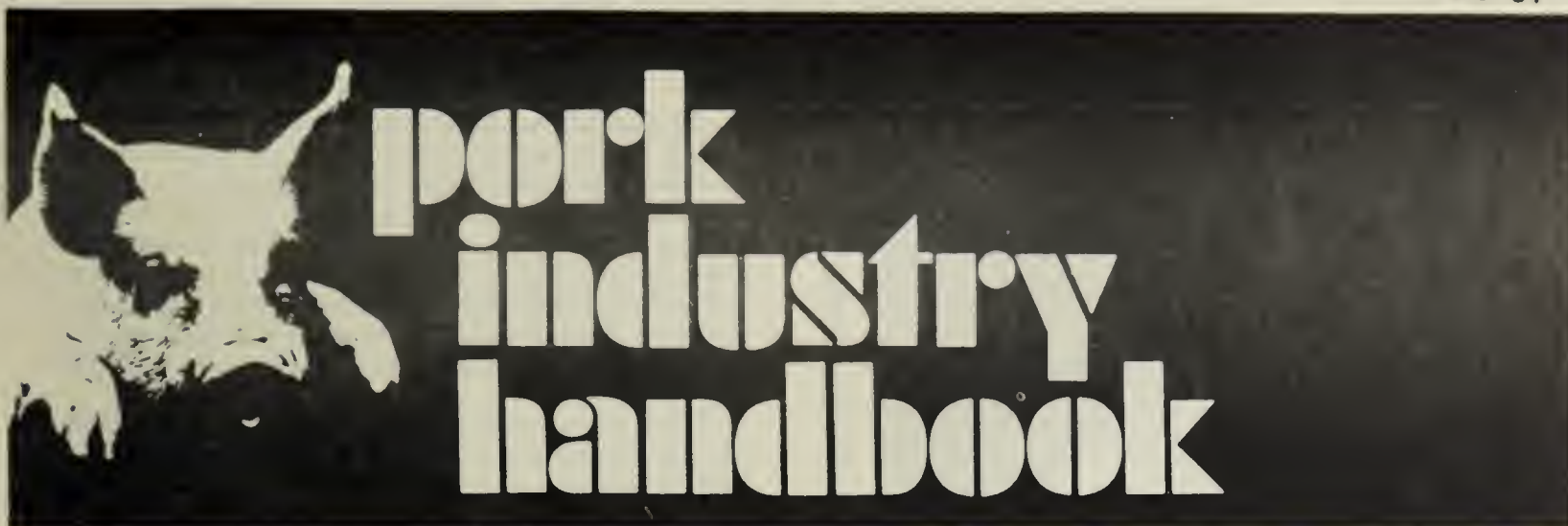
1. First week after weaning—breed sows.
2. Three weeks before farrowing—treat for internal and external parasites.
3. One week before farrowing—repeat treatment for internal and external parasites.
4. At 110 days after breeding—thoroughly wash sow, move to farrowing facility; begin feeding laxative ration.
5. From 111 days to farrowing—observe for signs of approaching farrowing. Attend at farrowing, or make judgment that attendance is not warranted.
6. Provide special care for weak or small pigs, and for large litters. Observe sow and litter for signs of problems.
7. By 10 days post-farrowing—bring sow to maximal feed level.
8. Cull sows at weaning on basis of productivity, temperament, and other economic factors.

Summary

1. Institute and maintain a disease-prevention, health-maintenance program for all brood stock at all times to protect sows and litters from diseases at and following farrowing.
2. Record breeding dates, calculate farrowing dates, and observe sows closely during late gestation to assure that sows are moved to the farrowing facility by the 110th day of gestation.
3. Farrowing will usually occur within 24 hours after milk is present. As farrowing approaches, sows may be restless and excitable; some may be vicious.
4. Treat sows twice for internal and external parasites within the shortest recommended time (for products used) before moving to farrowing facility.
5. Feed a ration with laxative effect from 110 days through the first week after farrowing.
6. Attending sows at farrowing can prevent death of pigs

due to trauma, biting, suffocation in membranes, and weakness.

7. Normal farrowing may be completed in less than 1 hour, or may exceed 5 hours. Injection of oxytocin can shorten total farrowing time but should not be used if there are indications that the birth canal may be obstructed.
8. Manual assistance in delivery of pigs should be undertaken only when signs indicate inability of the sow to deliver unassisted; use arm-length glove, lubrication, and inject an antibacterial solution if manual assistance is necessary for delivery.
9. All newborn pigs should receive colostrum. Extra care for weak or small pigs and for large litters can result in more pigs weaned.
10. In the first few days after farrowing, observe sows and pigs carefully for evidence of disease condition or inadequate milk production or intake.
11. After farrowing, increase daily ration gradually; attain maximal feed level by 10 days; maximal amount should be based on number of pigs in the litter.
12. Production level, temperament, and other economics of using sows vs. gilts should determine when sows are replaced.



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Artificial Insemination in Swine

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The techniques and equipment necessary for artificial insemination (AI) in swine are readily available. When considering whether or not to use AI, two factors are noteworthy: the potential for disease control and the potential for genetic improvement. Other factors make AI attractive. For example, AI allows for the development of the closed herd, where no animals are brought into an existing herd. AI makes it possible for any size operation to bring new genetic material into the herd with minimum risk of introducing new disease organisms. When sows are placed in gestation crates after breeding, AI removes the necessity of taking the sow out of the crate for a second insemination 12-13 hrs. later. One drawback with the use of AI is that a higher level of management is required; however, several benefits result from the greater input of managerial skills. For instance, with better records, a greater awareness of the true reproductive status of the breeding herd will result. Subsequently, more effective selection of breeding stock can be carried out.

Heat Detection

The most critical factor in achieving maximum conception rates with AI is to inseminate females at exactly the right time. To accomplish this, the breeder *must* practice proper heat detection. The normal estrous or heat cycle of the pig is 20-22 days in length, but it can range from 18-25 days. The estrous cycle can be broken down into segments—the period of male receptivity (standing heat or estrus), lasting from a few hours to several days, and the nonreceptive period. The average length of estrus is 1-2 days for gilts and 2-3 days for sows. If the length of estrus is longer or shorter, the chances of picking the right time to inseminate a female are lower.

Estrus detection is a simple technique. The difficulty is in being sure that detection is carried out correctly. When the female is in heat, she often will try to find the boar herself. There may or may not be evidence of swelling of the vulva. In the presence of a male, the female will assume the mating stance; that is, she stands solidly when pressure is applied on her back. The final sign of standing heat is the "ear popping response," where the female's ears will repeatedly move toward an erect position as she assumes the mating stance. Determining the correct time to breed is based on the time the female first shows heat. Therefore, the more frequently heat detection is done, the more likely it is that insemination will be carried out at the appropriate time.

Based on frequency of heat detection, Table 1 presents a "rule of thumb" to determine the appropriate insemination time for fresh semen. When using frozen semen, twice daily heat detection should be the rule, and insemination should be delayed until 2-4 hrs. prior to expected ovulation time or approximately 24-30 hrs. after the onset of estrus. Ovulation occurs about 40 hrs. after the onset of heat.

Table 1. "Rule of thumb" for frequency of heat detection and time to inseminate females in heat.

Frequency of heat detection	Best time to Inseminate*
Once daily	Every day they stand
Twice daily	12 and 24 hours after onset of heat

* If in heat longer than three days, discontinue inseminations.



Figure 1. Method of detecting estrus in females. Note the erect ears and rigid stance with pressure applied to the back in the presence of the boar.

The best method of heat detection is to check each female in the presence of a boar by applying back pressure (try to sit on her back) to see if she will assume the mating stance as described earlier (Figure 1). Unless these criteria are met, the time of ovulation cannot be estimated accurately. Using a boar in combination with hand pressure is the most accurate method of finding females in heat. Researchers have shown that the presence of a boar increases the chance of detecting all females truly in heat by 30-40%.

If you must use a boar to check for heat, how does he fit into the AI program? First, the heat check boar can be raised on the farm. As the heat checker, he should be vasectomized. Second, by using AI, fewer, but genetically superior, boars can be used to breed many more females than with natural service. The average boar produces enough sperm to impregnate approximately 1500-2000 females a year. In a normal pen breeding system, a boar rarely breeds more than 200-300 females per year.

Boar Training and Semen Collection

Training a boar for collection of semen can be the most frustrating part of AI unless extreme patience is used in handling the boar; but with this patience, semen collection can be easy. Boars can be trained to mount a dummy sow or a sow in heat. The dummy sow is preferable since there is no size incompatibility, nor is there a problem with a sow that won't stand still long enough for ejaculation to be completed. A simple plan for a boar collection dummy is shown in Figure 2. It is usually easier to train a young boar that has had no sexual contact with females than to train an older, experienced boar. Some boars probably can never be trained, although these are infrequent. These are likely to be the "shy breeder" type.

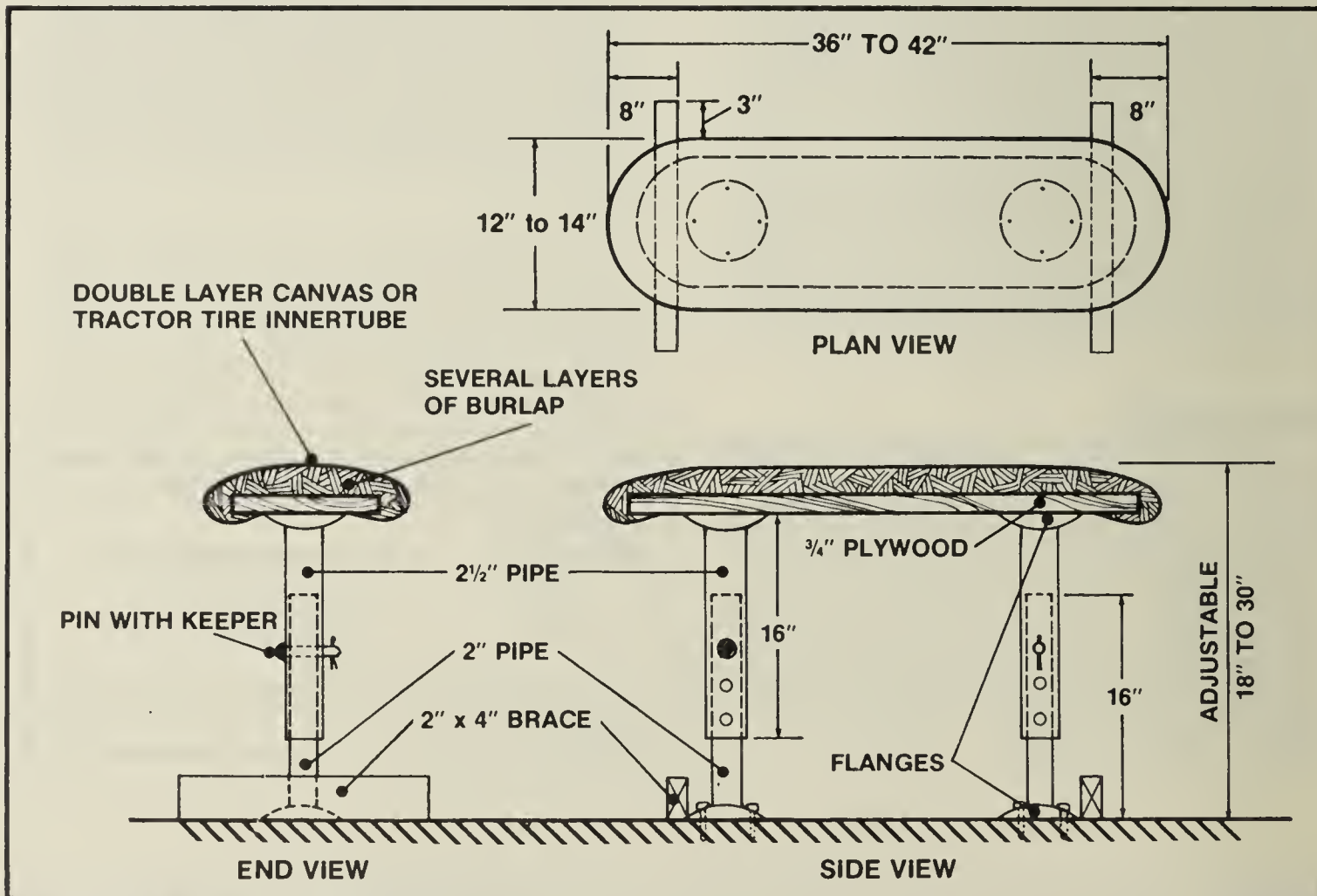


Figure 2. Boar collection dummy.

As soon as a young boar starts to rant, or at approximately 7-8 months of age, he can be brought into contact with the dummy sow to start training. Don't expect a boar to mount the dummy at first contact. Patience is very important. Handle the boar with care so that he will get acquainted with the collector and the dummy. Be sure the dummy is placed where there is adequate room to move around and where the floor is not slick. The dummy should be securely anchored so it can't be turned over.

If no mounts occur the first time or two, sprinkle semen, boar urine or fluid from the sheath of a strange boar on the ends of the dummy. Urine from a sow in heat is much less effective than the odor of a strange boar. If there are still no attempts to mount, try bringing several females in heat into the same area as the dummy, and allow the boar to mount a female in estrus several times. If there are further failures to mount, try collecting semen from the boar by placing a sow in heat close to the dummy; later, try collecting the semen using the dummy alone. An alternative method is to try collecting from the boar by using a female in heat adjacent to the dummy, later lifting the boar over to the dummy to finish collecting. If all attempts to use a dummy fail, then you may be restricted to using a sow in heat for each collection.

The stimulus for ejaculation in the boar is pressure applied to the spiral portion of the penis (Figure 3). Once the boar mounts, allow him to start thrusting; then quietly ease down beside him, and grasp the penis firmly enough to retain a grip, using your bare hand or a rubber glove. At the same time, begin pulling the penis (gently) from the sheath, and rapidly increase the pressure and pulling action until thrusting stops. Some boars require what seems to be tremendous pressure to stimulate ejaculation; others require only slight pressure. Occasionally a boar will start backing off or sliding off the dummy or even a sow when your hand touches his penis. To help prevent or correct this problem, one of the following may be helpful. If you're collecting from a dummy (Figure 2), try attaching a piece of pipe or a board, 2 in. x 4 in., to the bottom side of the dummy perpendicular

to the length at about the half-way point. This will give the boar something to hook his front legs around. Normally an artificial vagina is of no value, but in the case of the shy-breeder type boar, it may facilitate obtaining a collection impossible to get otherwise. Fill the outer jacket of the device with 100 F water, and lubricate the open end. Guide the boar's penis into the open end, and wait for ejaculation to take place.

There are several phases to ejaculation. The first portion may consist of clear fluid and some gel-like substance. There are no sperm in this portion so it need not be collected. Then the sperm-rich fraction starts (creamy white), followed by more gel and clear fluid. Some gel will be noticed along with the sperm-rich fraction. There will be several alternating phases of sperm-rich and sperm-free fluid; the sperm-free phases need not be collected. The time for ejaculation can be as short as a minute but may be as long as five minutes. The average volume will vary somewhat with each boar, but approximately 150-200 cc (1/3 - 1/2 pint) can be expected (see Table 2).

Table 2. Semen characteristics and sperm output of boars.

Characteristics of average ejaculates

Number of semen collections per week	2-5
Volume (ml)	150-200*
Sperm concentration (million/ml)	200-300
Total sperm/ejac. (billion)	30-60
Total sperm/week (billion)	120-150
Motile sperm (%)	70
Morphologically normal sperm (%)	80

* Gel-free volume



Figure 3. The stimulus for ejaculation in the boar is pressure applied to the spiral portion of the penis.





Semen Evaluation

Figure 4 shows the equipment necessary for collecting semen. A wide mouthed thermos bottle or a plastic (pint size) bottle with a narrow mouth can be used. If the thermos is used, consider placing a couple of layers of cheesecloth over the mouth to strain out gel and to prevent dirt from falling into the semen (Figure 3). The plastic bottle should be covered with 1 in. of foam rubber for insulation.

During and following collection, protect the semen from a rapid change in temperature. The insulation from the thermos or the foam is sufficient protection to prevent sperm damage for 5-10 minutes at 20 F. In a warm room (60-70 F), strain the gel from the semen (through a couple layers of cheese cloth) if not strained during collection. Note the volume of semen, since this will dictate how much extender you will need to add, depending on the number of females to be bred and whether or not semen will be stored. Throughout the collection and insemination process, care should be taken to be clean and sanitary.

Normally semen will have a chalky, creamy appearance, indicating high sperm concentration. As concentration gets lower, the opaqueness diminishes. A microscope is not essential to make an AI program work, but it could be useful. If you desire to use one, check it to verify concentration and motility and to check for abnormal sperm. Accurate sperm counting would require additional equipment. Motility, or the forward movement of sperm, was once thought to be a good indicator of fertility. However, visual observation of sperm is not a sure indicator of fertility. The only way to be certain is to test-mate prior to the breeding season. The test-mating does not, however, insure that the boar will remain fertile for the entire season.

Frequency of collection depends on the need for sperm. Ideally, a boar should be collected no more than two or three times a week to maximize sperm concentration and semen volume. When the need arises, collection once or twice a day can be maintained for 3-5 days; however, sperm numbers and sex drive diminish rapidly. This does vary to some extent with the individual boar.

The average ejaculate contains enough sperm to inseminate at least 6-8 females. The best rule to follow is to

use the sperm as soon as possible after collection. Two factors are considered in insemination: number of sperm and volume of fluid. It has been shown that a minimum of two billion live sperm in an adequate volume of fluid are required to obtain adequate conception rates. Since some sperm will be dead, more than two billion are needed. Researchers have shown that approximately 50 cc fluid volume is close to the minimum, and it is recommended that 100 cc total volume be inseminated to maximize conception.

How much an ejaculate must be extended depends on the volume of the ejaculate collected, the number of females to be inseminated and whether or not short term storage will be used. If five females are to be inseminated with fresh semen, a total volume of 500 cc of extended semen is needed. If the ejaculate contains 100 cc, then 400 cc of extender is required to obtain the required 500 cc for five females. If some semen is to be stored for future use, then a higher rate of extension would be used, and microscopic verification of sperm concentration may be advisable. However, AI should be a routine procedure in herd management before short-time storing of semen is considered. Storage for more than two days is not advisable in most instances.

Before extending the semen, measure the temperature of the ejaculate with a good thermometer, and raise or lower the temperature of the extender to within two degrees of the semen. Gently but thoroughly mix the two. The extended semen is now ready for insemination or storage. For storage, allow the mixture to cool to room temperature, 70-75 F. Place the container of semen in a small styrofoam box or in a pan of water (same temperature as the semen), and put both in a refrigerator to maintain a temperature of 55-60 F. Since temperature varies greatly between refrigerators, check ahead of time to be sure the appropriate temperature can be maintained. These precautions are necessary to prevent the mixture from cooling too rapidly, thus causing damage to the sperm.

Usually, semen can be extended at a ratio of 1 part strained semen to 4-5 parts extender without any problem. Higher rates of extension very likely would not result in a

decrease in conception unless a ratio of 1:10 or greater is used. Then it is advisable to get an estimate of actual sperm concentration so at least 3-4 billion sperm are inseminated. To maximize litter size and conception rate, investigators have shown that the use of two or more ejaculates pooled from different boars can be advantageous.

Two formulas for semen extender are presented in Table 3—BL-1 and Egg Yolk. The BL-1 extender is available commercially and can be stored in dry form until needed. Either extender can be stored frozen. Freezing into cubes is a good storage method that is convenient to use.

Skim milk may be used as a semen extender if the following steps are taken prior to mixing with semen: (1) Heat in a double boiler to a temperature of 88-90 C (190-195 F) for 8-10 minutes. Be careful not to scorch the milk. (2) After cooling to room temperature, break one egg and add the egg yolk only (minus the membrane) to one quart of milk. Carefully mix for about 2 min., so as not to raise a froth. (3) Equalize (within 2 C) the temperature of the milk with that of the semen. (4) Add the extender to the semen by slowly pouring the milk down the side of the container. Semen extended with skim milk should be used immediately. Additional information regarding extenders, as well as other information, can be obtained with the aid of your state swine Extension specialist.

Table 3. Extenders for use with boar semen.

Component	BL—1 (1 quart)	Egg Yolk Extender (1 quart)
Egg Yolk (cc)		317
Distilled Water (cc)	*	739
Glucose (gm)	27.4	31.7
Potassium Chloride (gm)	.3	
Sodium Bicarbonate (gm)	1.9	1.6
Sodium Citrate (gm)	9.5	
Penicillin, (million Int. Units)	1	1.1
Streptomycin Sulfate (gm)	1	1.6

* Put salts in a clean quart container and fill to line with distilled water.

Insemination

Having already penned estrus females conveniently, take a breeding catheter, and apply light mineral oil, vegetable oil or KY jelly to the catheter for lubrication. Both the rubber spirette or the plastic type catheters will work; however, there are advantages and disadvantages to both. Many producers prefer the spirette because it is shaped much like a boar's penis, and the female's reproductive tract grips the spiral end just as it would during natural mating. This helps minimize backflow and also is a fair indicator of estrus. In addition, the spirette is flexible, and there is very little chance of injury to the female. The disadvantage is that it must be cleaned promptly after use each day. Unless used in a purebred herd or a known disease condition is present in the herd, the same catheter can be used for several females. When a positive record of ancestry is necessary, use a clean catheter for each female. In contrast to the spirette, the diameter of the plastic bovine or bent tip type of catheter is small enough that the female tract cannot grip it. Consequently, there is a greater chance for backflow to occur. Usually backflow is not a serious problem unless sperm numbers are expected to be at the minimum requirement, such as with frozen semen. With hard plastic catheters, there is a greater risk of injury to the female. Also, if the female is nervous or jumpy, the bovine

catheter will slide in and out with every move, unlike the spirette type which is gripped tightly, flexes and bends, and usually doesn't fall out, even if the sow jumps away from the inseminator.

Seldom do females need more restraint than being confined to a small pen. Tight restraint or snaring should be avoided. Sometimes haying a boar close by will help a nervous female to stand more solidly for insemination.

For insemination, put about 100 cc extended semen in a squeeze bottle (4 oz. size) with a cone-shaped tip (see Figure 4). A large syringe can be used but is more difficult to handle. During cold weather, put the bottle of semen in a protected area, such as a styrofoam box or your shirt pocket, until ready to inseminate the female.

Place a few drops of lubricant on the tip of the rubber spirette (not needed for the bovine type), and insert the tip into the vulva, pointing it toward the backbone to avoid the opening of the urethra. Slide the catheter along the top of the vagina until rather firm resistance is felt. The cervix is usually 8-10 in. (16-25 cm) inside the vulva but could be deeper in larger females. In some gilts, resistance may be encountered about 4 in. (10 cm) inside the vulva. This may be the remains of a membrane (hymen). When the cervix is detected, start rotating the rubber spirette counter clockwise (left hand thread) until it becomes "locked" into the cervix. The opening into the cervix is nearly impossible to miss as it has the shape of a funnel. Occasionally, a female will not clamp down on the spirette. This occurs mostly in sows or if the female is not in heat. Insert the bovine catheter until the tip is deep into the cervix, being careful not to penetrate into the uterus where injury could result.

When the catheter is in place, connect the semen container, and begin squeezing the semen through the catheter. If semen starts running out of the vulva (backflow), release the pressure, wait momentarily, and start again. Allowing the female to move around often helps minimize backflow. There are times when it seems nearly impossible to force the semen into the female—the opening of the catheter may be jammed against some tissue. Work the catheter around and continue. Check the opening of the squeeze bottle; it should be about 1/32 in. in diameter.

Cleaning AI Equipment

Following use, do not allow semen or other material to dry in the equipment. Use plenty of clean water for rinsing. Do not use soap or detergents to clean anything that will come in contact with semen since there will likely be residues that are harmful to sperm. Clean thoroughly with a brush and tap water to remove any gel particles left. Rinse all pieces in distilled or deionized water; then boil in distilled or deionized water for 20 minutes. Do not boil in tap water as this will leave a mineral deposit on the equipment. If you are not able to boil the equipment, a temporary sterilizing method is to rinse thoroughly with 70% alcohol. However, do not depend on the alcohol for continued use since some organisms are immune to its effects.

Frozen Semen

Frozen semen is available from one commercial source in the United States and one in Canada. However, before obtaining semen from Canada, be sure the shipment is cleared with customs and with the Animal and Plant Health Inspection Service (APHIS). Check the records accumulated for each sperm-donating boar under consideration. Your choice is just as important as if you were buying him for a permanent replacement. Evaluate the usual data regarding boar performance, but more importantly, evaluate data on his conception rates, litter size, and his progeny's

performance whenever available. Remember, the sperm of some boars do not survive well during the freezing and thawing process; therefore, it is important to check the performance record of the boar before using him.

The frozen semen state-of-the-art is not equal to freshly collected semen. On the average, conception rates will be 10-20% lower, and litter size will likely be about one pig less per litter. Apparently the freezing and thawing process alters the sperm in such a way as to make them more fragile. Being more fragile, the sperm must receive special handling as outlined in the thawing procedures received with the semen shipment.

Records

A certain amount of record keeping is advisable. Records of female identification and the dates in standing heat are valuable in scheduling breeding and in determining the volume of semen required at the next breeding period. In addition, through records, irregular cycle lengths, anestrus and other reproductive problems will become more evident, allowing corrective measures to be taken. A record including date of semen collection and strained volume should be maintained for each boar. These records may also include notes of the type and duration of any sickness the boar may experience. Anything that causes body

temperatures to go up as little as 1-2 F can result in a 60-80% decrease in total numbers of viable sperm for several weeks. The normal body temperature is approximately 102 F — plus or minus 1 degree F.

Summary

To introduce new genetic material into your herd at a minimum risk of disease and to increase the use of a particular sire, the pork producer should consider an AI program. Providing a viable possibility for herd improvement, an AI program will require greater managerial input, but will result in greater awareness of any reproductive problems in the herd. A minimum of specialized equipment is needed to carry out a successful program. One of the best uses of AI is in bringing new genetics into the herd using frozen semen and semen collected on the farm for expanded use of fewer but superior boars. If a few simple suggestions are followed, AI will yield conception rates and litter size equal to or better than natural service.

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The Environment in Swine Housing

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Trends to year-round farrowing and some confinement of the whole herd changed swine environments along with accommodations. The pigs have adapted fairly well, but new problems have come up. Environmental management is a critical element of time-intensive, space-intensive pork production systems.

Some argue that the modest improvement in swine performance in recent decades—despite marked enhancements in diet and genetic makeup—is due to unspecified adverse effects of the environments provided for the animals. All agree that housing is high on the list of pork industry problems.

The pig's environment is extremely complicated, and present knowledge of it and its effects on pig performance is relatively limited. There are, as yet, no pat remedies for environmental ills in swine houses. Thus, in environmental management we still must resort to knowing principles and how to integrate and apply them.

Further, each facility presents a unique set of surroundings. Each environmental problem must be considered in detail and in a way that accounts for all relations among its many parts.

Focus of environmental management: the pigs

The pig quickly responds to environmental stresses to survive and reproduce in adverse surroundings. These adaptations take the form of changes in body functions, structures and behavior.

Unfortunately, the pig's adaptive responses are often counter-productive in terms of swine performance. Some depress processes associated with growth, reproduction or lactation. Others impair disease resistance. All waste nutrients and lead to stragglers.

The pig must counteract specifically the particular stresses present, but its initial reaction to any stress includes a nonspecific component—increased secretion

of glucocorticoids by the adrenal glands. These hormones in high concentrations support the animal's short-term survival, but they also mobilize amino acids from precious muscle proteins and interfere with some mechanisms of immunity against infectious diseases.

Minimizing environmental stresses is a key to profitable pig performance.

Assessing swine environments

While the swine-house environment is complex, most of its elements can be measured. Interpreting results of such measurements in terms of what they mean to pig well-being, facility operation and pork production economics remains a dilemma. This is largely because environmental factors interact with one another: the effect of one stressful factor on the pig depends very much on the nature of the rest of the environment. For example, a draft is more harmful in a cold, wet place than in a warm, dry one.

Advances have been made as experience has been gained in recent years. But often the troubleshooter still must engage in trial and error to identify the problem. Following are some points to be considered when assessing swine environments.

Consider all environmental factors. Environment results from all external conditions the pig experiences. Elements that cannot be readily measured or controlled influence the pig's health and performance, too, so even these should be considered so far as possible.

Remember interactions. The environmental complex acts as a whole on the pig. Combined effects of two or more environmental components are often difficult to evaluate and control, but nonetheless they should be considered.

Environmental factors vary over space at a given time. Values obtained at one place in a pen or house may not hold for other locations. It is important to measure environmental variables where the pig experiences them—in its microenvironment.

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They also change with time at a given place. A swine facility may be occupied continuously. Because environmental factors and occupancy vary with time, needed control measures do, too. This is especially so when days are warm and nights are cool. Environmental assessments and control schemes should take daily and seasonal environmental cycles and variations due to short-term weather events into account. Of course, the pig readily adjusts to environmental cycles as long as the extremes are not unduly stressful.

Rate of environmental change is critical. Abrupt environmental changes tend to be more stressful than changes occurring over a longer period. For example, preconditioning young pigs to a cool environment before moving them from an enclosed nursery to an open-front house during cold weather reduces stress.

Pigs modify their own environments. Pigs give off heat, water vapor, urine and feces, and shed disease-causing organisms. Thus, the animals' own processes help determine the nature of their microenvironment. Changes in age or number of pigs in a facility alter animal impacts, and, therefore, the control measures required.

Beware. There is a tendency to assume that if a human is comfortable in a certain environment, a pig would be, also. Beware of this pitfall. Pigs may be more or less sensitive to a certain stressor than are humans. Manage swine-house environments with the pigs' needs in mind.

Thermal environment

The pig regulates its body temperature by balancing heat loss against metabolic heat and heat gain. As the difference between body and environmental temperatures becomes greater, heat-loss rate increases.

Effective environmental temperature. The environment's demand of heat from the pig is determined largely by air temperature, radiant-environmental (wall and ceiling) temperatures, air speed and floor characteristics. Take 80-lb. pigs, for example (the principles hold as well for swine at other stages of life). In a house with walls and ceiling 5 F. cooler than the air and a 1 ft./sec. draft across the animals, effective temperature is 15 F. lower than air temperature. If these pigs are on a concrete-slat floor, effective temperature drops another 10 F., but with straw bedding the adjustment is +7 F.

Lower critical temperature. Body size, thermal insulation, feed-intake rate and group size determine the effective temperature below which pigs must increase heat-production rate to keep their bodies warm. Considering 80-lb. pigs again, when consuming 3.2 lb. of feed daily in a group of four, lower critical temperature is 63 F.; when taking in 4 lb. daily and in a group of nine, it is 50 F. Similarly, for early-pregnant sows consuming 3.7 or 7.7 lb. of feed daily, lower critical temperature is 75 or 65 F., respectively. By late pregnancy it has dropped 10 F. in both cases.

Feed or fuel? During cold weather, the manager may (1) raise environmental temperature to reduce environmental heat demand, (2) increase the pig's heat gain by means such as a radiant heater, or (3) let the pig raise its metabolic rate to produce more heat itself. The first two options require fuel or power, the third feed.

How much extra feed is required to keep the body warm? Again referring to an 80-lb. pig, for example, when effective environmental temperature is 20 F. below the pig's lower critical temperature, the pig would need to consume around $\frac{1}{4}$ lb. additional feed daily just to keep body temperature normal. The dry sow's feed allowance should be increased when environmental temperature falls below 70 F.; at 50 F., for example, the sow should receive an extra $1\frac{1}{2}$ lb. daily.

"Humidity." The pig relies less on evaporative heat loss than many species do, so high vapor pressure, which suppresses evaporation, is less critical for swine. Vapor pressure has little influence on the well-being or performance of swine unless air temperature exceeds 90 F. Moisture control is nonetheless necessary in swine houses as damp surroundings favor both survival of pathogens and structural deterioration of the building.

Air distribution. Effective ventilation depends on uniform air distribution in a swine house. Drafts may cold-stress the animals, while stagnant areas may lead to heat stress. Thus, knowledge of air-flow patterns is essential to an understanding of the pigs' thermal environment.

Regardless of whether natural or mechanical ventilation is employed, air flows as it does inside an animal house largely because of its density as it comes in. Warm air entering through an inlet under the eave or in the ceiling is buoyant and tends to continue moving along the ceiling to the outlet. It mixes with house air before reaching the animals. But when incoming air is cooler and denser than house air, it tends to drop to pig level before mixing.

In many parts of the country, during the seasons of change, incoming air is "warm" during the day, but "cool" at night. On such days, primary and secondary air-flow patterns within the house change twice daily. As this reversal occurs on such an evening, the pigs may experience some rather sudden environmental changes as air temperature drops and air speed rises.

Air-flow patterns in swine houses are controlled mainly by inlet position, assuming adequate fan capacity. Inlet-opening size influences the air's speed as it enters the house, and this, in turn, has a large effect on air distribution. Further, air may be directed to a certain extent by inlet baffles.

When an exhaust-fan system is used during winter, cracks and gaps in the building may become inlets for small jets of cold air. These airstreams may cold-stress nearby pigs.

Even in environments in which the air is normally still, application of radiant heat sets into motion convective eddies that partially erase any beneficial effect of the radiant heat itself. This is especially harmful when the draft so created carries to the pig cold air that has just dropped into the house from the outside.

The newborn piglet. The piglet's lower critical temperature is around 95 F. The piglet's total heat-loss rate is $\frac{2}{3}$ higher in a 70 F. environment than in one at 85 F. Evaporation from skin and respiratory passages leads to less than 10% of its heat loss, regardless of effective environmental temperature. No more than 15% of the piglet's heat loss is to the floor, so floor temperature has relatively little effect on total heat balance. Nevertheless, heat loss rate to the floor is twice as great on concrete as on wood, for example.

The remaining 75% of the piglet's heat loss flows by either radiation or convection. Thus, environmental conditions that affect these flows are important determiners of the piglet's thermal comfort.

Wall and ceiling temperatures are major factors in radiant heat loss, whereas air temperature and speed largely influence convective heat loss. Dropping wall and ceiling temperatures by 20 F., even when air temperature remains the same, increases the piglet's total heat loss rate by around 20%, which emphasizes the need for a well insulated farrowing house.

Disease and environment

The environment exerts various influences on the incidence and severity of infectious diseases.

Environment and microbe challenge. Pathogenic agents—bacteria, viruses, spores, oocysts, worm eggs, and so on—reside in the environment as they pass from one pig to another. The nature of the surroundings determines how long they can challenge another pig.

The presence of organic matter and moisture and the limited sunlight in closed swine houses all favor survival of pathogenic forms. In general, cooler environments also enhance pathogen survival because they retard drying, the major cause of pathogen death outside the pig.

Air humidity affects the rate at which feces dry, and fecal bacteria die 10 times faster when relative humidity is 40% than when it is 80%, for example.

Slotted floors help separate the pig from the pathogens its feces contain. However, disease-causing bacteria may survive for months in underfloor waste, and may be aerosolized when the slurry is disturbed and be wafted by air currents back into the pig's microenvironment. Worm eggs also accumulate in wastewater, even when it flows into a lagoon, which can cause problems when wastewater is used to flush gutters.

The incidence of infectious disease increases the longer a house is occupied. "Disease build-up" can be checked by depopulation and disinfection. A recent trend has been to batteries of rooms in swine houses, each operated on the "all-in, all-out" principle instead of continuously. Some recommend no more than 200 pigs in one air space to make it easier to contain an acute disease outbreak.

Vectors of pathogenic agents pose a special problem; they usually give no clue to their role. Many microbic diseases of swine can be spread by wild birds and rodents, and even by barn cats. Humans commonly carry swine pathogens from place to place, and this can be reduced greatly by using footbaths or changing footwear and changing coveralls between areas and by not touching the animals themselves. The most effective vector, however, is the carrier pig. The premises may be immaculate otherwise, but if a carrier is present, all efforts in disease management are in vain. On the other hand, the origin of a pathogen may be exotic. For example, sawdust may be contaminated with bacteria that cause mastitis.

The manager decides the level of sanitation largely on the basis of history. When overt disease has been absent, a thorough dry and wet cleaning after the house or pen is emptied may suffice. But some have come to prefer a routine program of terminal cleaning and disinfection.

Environment and pig resistance. Intestinal and respiratory maladies of swine often result from infections by opportunistic pathogens. Under usual circumstances, the pig's defenses control these infections to the point that disease does not follow. But stress may reduce the animal's resistance, and disease blooms.

As discussed earlier, glucocorticoid secretion rate rises during the initial phase of an animal's nonspecific reaction to any stress. While these hormones at lower levels in the blood support defense mechanisms, at high concentration they impair resistance by interfering with antibody formation, reducing counts of certain white blood cells, hampering detoxification mechanisms and depressing microbic-clearance processes.

Air environment

The pig's respiratory tract is in intimate contact with the air and consequently, in closed houses, with air pollutants. Those of major concern include microbes, dust, and gases and odorous vapors, all arising from the pigs and their activities. Air pollutants may affect pig performance directly by altering metabolic reactions or indirectly by influencing pig health. Caretakers may also be affected.

Bacteria. Concentration of airborne bacterial particles in a closed swine house ranges from around 500/cu. ft. during warm weather up to around 10,000 during cold weather, the variation being due mainly to ventilation. In modified-open-front houses, the range is lower, 100 to 5,000/cu. ft., but still considerably higher than the 10/cu. ft. found in outdoor air. Vapor pressure and airborne bacterial concentration are generally related inversely; moister, heavier particles settle faster.

Most of the airborne bacteria in swine houses are staphylococci or fecal streptococci; coliforms are scarce. Roughly 20% of the staph and strep particles and 10% of the coliforms are small enough to be drawn all the way into the lungs. In addition to bacteria that arise from the pigs' skin and excreta, respiratory pathogens may also be present in air. Each sneeze aerosolizes about 40,000 microbe-laden droplets.

The pig normally can clear bacteria and keep its lungs relatively sterile. However, cold exposure and other stresses depress this process, predisposing the pig to respiratory infections.

Dust. Most of the dust in swine-house air originates in the feed. When ventilation rate is low, dust concentration in many swine houses approaches the threshold-limit value for human industrial occupancy of 0.3 mg./cu. ft. But even at this concentration, airborne dust has little direct influence on the pig's growth.

Gases and odorous vapors. Swine-house air is polluted by several dozen fixed gases and odorous vapors given off as manure decomposes. The most important of these, related to pig health and performance, are hydrogen sulfide and ammonia. At concentrations normally present in closed swine houses (less than 10 ppm), pigs tolerate hydrogen sulfide well. But when underfloor waste is agitated prior to removal, hydrogen-sulfide concentration above the floor can reach over 1,000 ppm—lethal to humans as well as pigs.

Ammonia is present in swine-house air at concentrations up to 100 ppm. At 50 ppm, atmospheric ammonia hinders the young pig's ability to clear bacteria from the lungs. It depresses growth in healthy young pigs when it exceeds 75 ppm.

Control measures. Control of air pollution can aim at prevention or elimination. Prevention centers on waste management and feed distribution. Biological and chemical preparations for odor control in swine houses may be beneficial in some cases.

Eliminating air pollutants depends mainly on dilution by ventilation. In addition, electrostatic precipitation can be used to reduce atmospheric concentrations of dust particles and the microbes and irritating chemicals they carry.

"Threshold sanitary ventilation rate" is the air-change rate that eliminates airborne transmission of infectious agents. It is much higher than economically feasible in swine houses. For both airborne bacteria and viruses, the higher the air temperature, the more quickly they die. As for vapor pressure, the viruses vary greatly in their susceptibility range, whereas midrange relative humidities, 50-80%, are most lethal to airborne bacteria. Air may also be disinfected when pigs are in the house.

Ultraviolet radiation, from the sun or a generator, kills microbes that it reaches, but airborne pathogens in swine houses are often coated with a protective layer of feces or mucus.

Behavior and environment

Behavioral maladjustments are often at the root of unthriftiness that shows up as stragglers.

Dominance order. Pigs grouped together organize themselves in a dominance order according to the outcome of fights during the first few days after grouping. The resulting social stability is an advantage, as little energy is further spent in combat and injuries are minimized. But there are drawbacks, too. Competition for feed spurs intake somewhat but much of the variation in growth among pigs is due to dominance-order rank. Under poor husbandry, especially when access to feed is marginal, the connection is more marked.

Group size and space allowance. Pig growth is not influenced by group size up to at least 40. But the dominance order seems less able to control aggression when space allowance is reduced. At low space allowance, pigs are more active and aggressive, which agrees with the sizeable effects space allowance has on growth and feed-conversion efficiency.

Mixing. The fights that result when strange pigs are grouped have little direct effect on growth, but they may reduce disease resistance or cause injury, and thus affect growth indirectly. Pigs should be mixed in a pen that is new to all, they may become extremely aggressive against intruders on home territory.

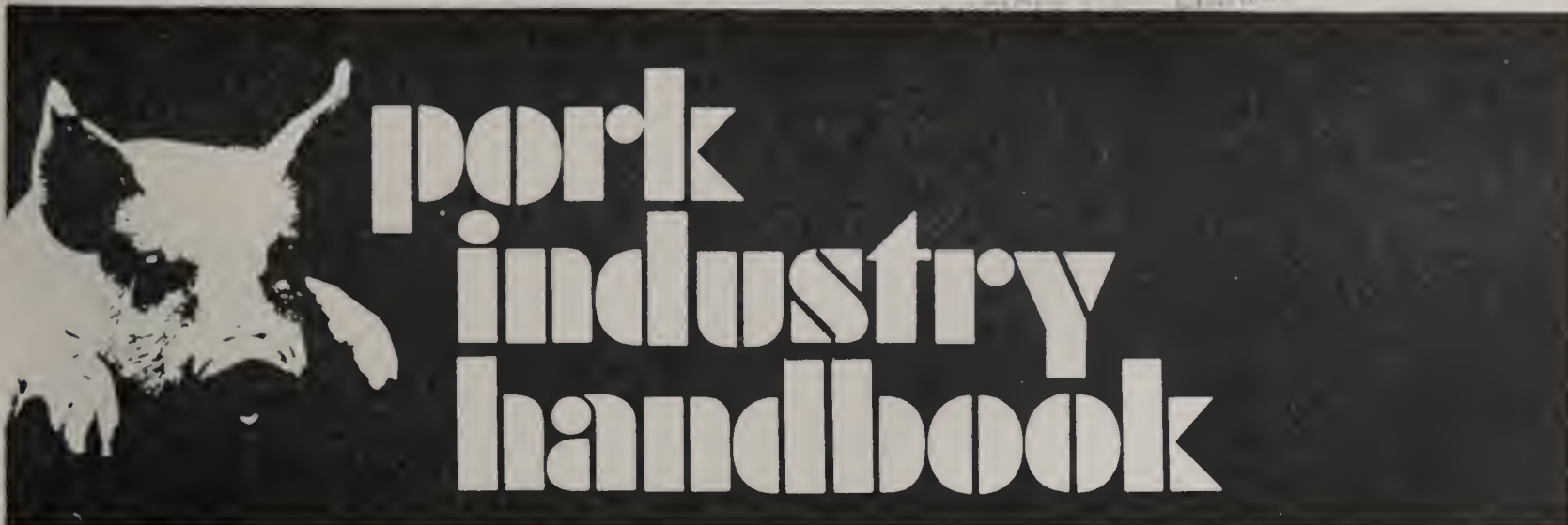
Frustration. In confinement environments, movement is restrained, the environment is monotonous, and the pig has scant chance to choose or alter its microenvironment.

For example, the sow kept in a crate prior to farrowing cannot fulfill her strong instinct to build a nest, and this interference may contribute to farrowing and lactation problems. Tethering gilts before puberty also has untoward consequences; the reproductive tracts of many of them never mature.

Pigs prefer comfortable surroundings, and they learn to operate devices that provide reward, such as a waterer. There is scope for training pigs to operate more control over their own environments. This may also reduce frustration.

Reproduction. The social environment young boars and gilts are kept in influences their reproductive function and behavior. Much sexual behavior is learned around the time of puberty. Young boars in homosexual, uniform-age groups cannot gain heterosexual experience when they are ready to learn, at 4 to 8 months of age. Often failure to "get boars to work" is due to lack of such social experience.

Gilts raised in confinement frequently reach puberty late or not at all. Sometimes a move outdoors triggers estrus. Group size is a factor, too. Gilts in groups of around 6 show heat more readily than those in larger groups, regardless of space allowance. Solid partitions between groups help, too. Keeping a boar near gilts also supports their reproductive development.



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Slotted Floors for Swine

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The development of slotted floors has been the dominant factor in making confinement swine production practical. Slotted or partially slotted floors make pens self-cleaning, leaving them clean and dry. The reduction of labor associated with clean, dry pens accounts largely for the feasibility of confinement production.

The question as to what type of floor to install in a confinement building depends somewhat upon how management intends to handle the waste. For example, if wastes are to be handled as a solid or semi-solid product, the floor will usually be solid. But if wastes are to be handled as a liquid, the floor will usually be at least partially slotted. Since slotted floors materially reduce the labor associated with most non-slotted floors, many existing confinement buildings, and perhaps most of the buildings of the future, will have slotted floors.

How Much Slotted Floor

Studies have generally shown no difference in performance when comparing partial versus total slats during summer. During winter, Nebraska studies showed an increase in feed requirement per unit gain with increasing amounts of slotted floor. For this reason, and because the initial floor cost increases slightly as the amount of slotted area increases, many floors for growing-finishing (G-F) pigs are from one-third to one-half slotted. This amount of slotted floor works well where the pen length is 24-26 ft., with about 10 ft. of this being slotted. Pen widths, in this case, are usually 8-10 ft. Wider or squarer buildings, with a center or off-center alley and pens on both sides with partially slotted floors, require pinpoint management to train pigs to dung on the slotted area. Buildings with a single row of pens, with the alley along the front or back with partially slotted floors, generally result in good dunging patterns. Thus, building dimension or arrangement may be a factor in deciding how much of the floor should be slotted.

Injuries to the claws have been shown to be greater on total slats as compared to partial slats. However, the effect of claw injuries on growth rate appears to be slight. Claw injuries to breeding swine, however, often lead to more

significant problems. Studies have shown that wider slats (8 in.) reduce claw injuries and clean as well as narrower slats.



Figure 1. Claw lesions of this type can be reduced by using wider slats (6-8 in.) that have a smooth flat surface and a slight pencil-round edge.

Since partially slotted floors are also partially solid floors, it is important for labor reduction and pig performance that pigs develop a desirable dunging pattern. As stated earlier, a long and narrow pen 8 or 10 ft. wide and 22 or 24 ft. long is preferred when floors are partially slotted. Pen shape is not important to dunging patterns on fully slotted floors. Assuming a long, narrow pen, there are

construction and management factors that are important in toilet training pigs. Perhaps no single item is fundamental, but rather several factors combined appear to have an additive effect of training the pig. For details, see PIH 11, Swine Confinement Growing-Finishing Units.

The floor configuration in farrowing houses varies among builders. Research results provide scant guidance in selecting farrowing house floor design. Houses with total, partial or no slats can be managed successfully. The present trend appears to favor 24-30 in. of slats at the rear of the crate, and 12-18 in. of slats at the front, with the middle section being solid.

Slat Width and Spacing

The most desirable dimension for slats depends upon material and class of pigs. Slotted floors should be designed to minimize pig injury while maximizing cleanliness. In general, the larger the pig the wider the slats that may be used without sacrificing performance and cleaning characteristics. Concrete slats may be made or are available in various widths. Concrete slats used for farrowing generally are 4-5 in. wide, nursery slats 4-6 in. wide and G-F slats 5-8 in. wide. Some of the metal and fiberglass slats for small pigs are as narrow as 1 in.

Factors such as amount of surface area slotted may influence the decision on what width slat to choose. Generally, a narrow spacing is required of narrow slats and a wider spacing, up to 1 in., is required of wider slats. Slat widths of 7-8 in. have been used very successfully for gestation and G-F pigs. Slat widths of this width definitely require a full inch spacing.

For slotted floored nurseries, the slat spacing should be either narrow enough so the pigs cannot get their legs caught at all, or wide enough (1 in.) so they can easily get their legs free should they step in the slot. When the wider spacing is used in the farrowing crate, a grate covering should be used at farrowing to cover the openings. The use of a grate is particularly necessary at the rear of the sow where wider slat openings are used. If the slat openings at the rear of the farrowing crate are not covered immediately prior to farrowing, and for several days following, the manager has no way of knowing if the sow has voided the placental tissue as it would go directly into the pit. Since a retained placenta may result in certain health problems for the sow and litter, the manager must know if and when the placenta was passed. Using a grate to overlay the wider slots at the rear of the farrowing crate until the pigs are a few days old also allows the baby pigs to adapt to slotted floors in stages.

Table 1. Suggested slat spacings.

Farrowing crate	¾ in., except at rear of sow where ¾-1 in. opening may be used.
Nursery (20-40 lb. pig)	½-1 in., depending on width of slat; wider slat/wider opening.
G-F (40-220 lb.)	¾-1 in., narrower slats of material other than concrete may use narrower openings. Wider slats, 5-8 in. need 1 in. opening.
Gestation or Boars	1-1 ½ in.

Slat Direction

In most phases of confinement production, slats that are placed parallel to the long dimension of the pen appear to favor pig comfort and mobility. Nursery, G-F and gestating pigs appear more mobile and comfortable when walking on slats that are parallel to the long dimension of the pen as opposed to slats that are placed at a right angle.

The foregoing assumes a rectangular shaped pen. Slat direction in total slotted floored buildings will be influenced

by other factors such as construction costs and the like. However, placing the slats parallel to natural traffic flow, so that the pigs will walk down a slat rather than across it, is worthy of consideration. The foregoing is true for farrowing and gestation crates or stalls, even though the animal is not allowed free movement.

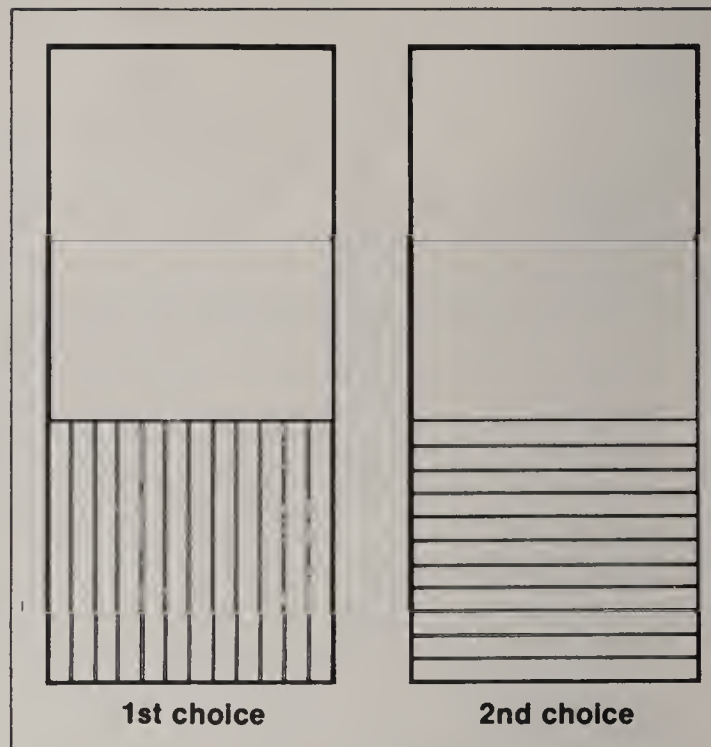


Figure 2. The recommended or preferred slat direction is shown on the left.

Slotted Floor Materials

Wood, concrete, metal and plastic have all been used effectively for slotted floors.

WOOD slats have the lowest first cost and also the shortest life. Oak is best, but other hardwoods such as hickory and maple can be used. Pig performance may be reduced by variable spacing resulting from warping (particularly likely to happen with slats less than 3 in. wide), wear, careless installation, insecure fastening and uneven heights. Wood slats can become quite slick. Their maximum life expectancy is between 2 and 4 yr., and even less in areas of intensive use, such as around feeders and waterers.

The recommended dimensions for wood slats are:

	A	B	C
2-ft. SPAN	3½-6 in.	2 in.	2¾-5 in.
4-ft. SPAN	3½-6 in.	2½ in.	2¾-5 in.
6-ft. SPAN	3½-6 in.	3 in.	2¾-5 in.
8-ft. SPAN	3½-6 in.	3½ in.	2¾-5 in.
10-ft. SPAN	3½-6 in.	4 in.	2¾-5 in.

The "A" dimension must be greater than the "C" dimension so the spacing will not become clogged. The slats are usually formed by ripping a rectangular timber on the diagonal, resulting in a vertical edge and an inclined edge. A second vertical cut should be made cutting off the sharp edge made by the diagonal cut.

CONCRETE slats are the most durable and have worked well especially for all hogs over 40 lb., including gestating sows. While they work well for smaller pigs and during lactation, slats made of other material work equally well here. Concrete slats can be precast by a concrete products plant, or commercial forms are available for casting the slats in place. Precast slats have the advantage of quality control during proportioning the mix, casting the slat and curing. Some concrete products plants are forming gang slats (two or more slats connected into one section) and complete 5 ft. wide and 8-12 ft. long farrowing sections.

Recommended dimensions for concrete slats are 5-8 in. tops with 4-5 in. depths (5 in. depth required for 8 and 10 ft. lengths).

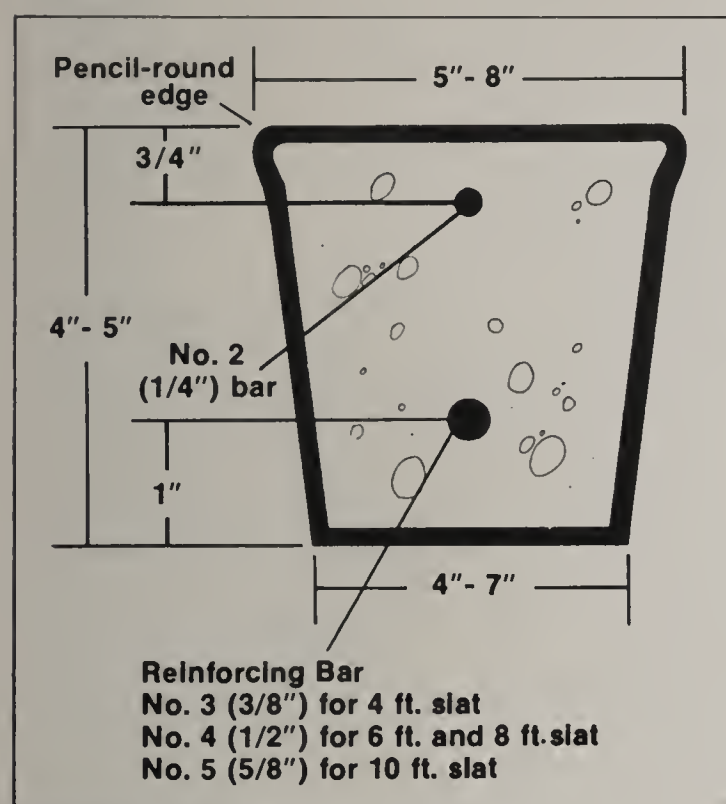


Figure 3. Example of concrete slat.

The ¼ in. bar in the top of the slat can be omitted when slats are cast in place and not moved. Use at least a 7½ bag mix of air-entrained cement with a 2-3 in. slump, a maximum-sized aggregate of ½ in. A slight pencil-round edge can be provided by edging the slats with a ¼ inch sidewalk edger. This will prevent chipping and further reduce foot injuries. Give the slats a smooth, steel-trowel finish to reduce leg and knee abrasions. This is particularly necessary for farrowing and nursery floor slats. For proper curing, protect the slats from drying out for 5 days by covering with plastic, by spraying on a curing compound or by covering with a wetted layer of straw.

METAL of various designs has been used. Flattened expanded metal (¾ in., 9-11 gauge) has proved to work well for pigs under 40 lb., but does not last as long as concrete when subjected to concentrated traffic of heavier animals. In farrowing crates, lay expanded metal so the long openings are parallel to the sow. Expanded metal with sharp edges should be avoided. Many of the early metal slats did not prove satisfactory because corrosion attacked the steel from the underside and caused failure

after 2-4 yr. Treating the underside of metal slats with epoxy paint or similar material extends its life. Steel grate 1-1½ in. wide and ¼-¾ in. thick has worked well when spaced ⅝-¾ in. apart for farrowing and ½ in. apart for nursery units.

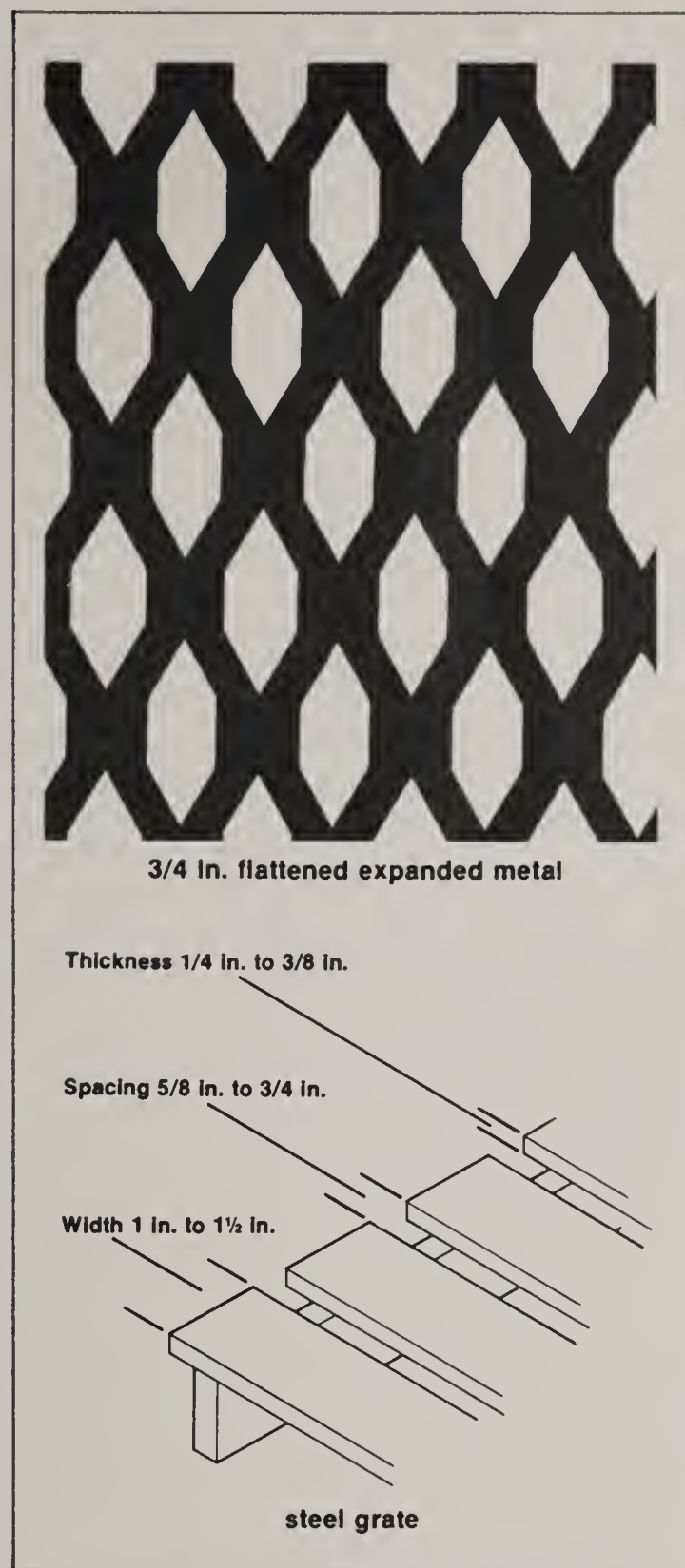


Figure 4. Examples of metal slotted floorings.

STAINLESS STEEL has become popular in farrowing and nursery units. The stainless flooring comes in 8½ in. or 12 in. wide planks. Some planks are welded together into a grate, and others are bolted together. Most of the stainless steel sections will span from 4-10 ft., depending on the depth of the side flange. A longer life is expected with stainless steel flooring than from plain steel. Porcelainized steel slats are also available.

ALUMINUM slotted flooring is available in several shapes from narrow "T" section to 8 in. wide punched sections. Aluminum cleans very readily, but some can be

slick for sows and heavier hogs. Aluminum must be insulated from other materials, particularly steel, to avoid corrosion.

PLASTIC slotted flooring of various shapes has become available during recent years. The plastic floors have the advantage of being somewhat warmer than concrete and metal, and they also clean readily. Plastic slats have been reported to be somewhat slick for sows and hogs over 100 lb. Some slat manufacturers have reported that a characteristic of PVC (plastic) is that it may develop a fatigue factor that is expressed as broken slats or a permanent sag. Because of this, plastic slats are currently somewhat heavier than those sold initially.

There has been recent interest in a 1½ in wide fiberglass reinforced plastic "T" slat for farrowing and nursery. The fiber strands in fiberglass are reported to interrupt the fatigue factor found in some plastics, thereby making them more durable. Fiberglass may also be slick, making it difficult for heavier pigs to walk. The most popular application for fiberglass and some types of plastic slats appears to be in partially slotted farrowing floors and nurseries. Most of the slotted floor materials used in farrowing and nursery pens could be used in flat-decks and double deck nursery units.

Floor Smoothness

Concrete floors (solid and/or slotted) that are rough have been shown to result in more injury, lameness and infection than smooth, clean floors. Therefore, concrete floors or slats should have a smoothness about equal to a machine trowel finish. Concrete slats that have a smooth surface and slight pencil-round edge result in fewer claw injuries and edges that chip less easily. The risk of getting a concrete floor too rough is much greater than getting it too smooth. However, a floor can become too smooth as well. Problems with floors too smooth are nearly always associated with solid non-slotted areas. In general, if the

floor is kept dry, and the slope does not exceed ½-¾ in. per foot, it is rare for problems related to slickness to occur.

Other Floor Related Problems

Knee and hock lesions among baby pigs in farrowing houses have been a problem to some producers, particularly in new buildings. Bedding usually reduces or eliminates the problem. Since most types of bedding cannot be used in a house with liquid manure disposal, other techniques are necessary. Wood shavings and sawdust have sometimes been used successfully in sparing amounts on the solid portion of a partially slotted farrowing pen, but extreme caution is advised. Secondary surfaces in the farrowing crate in the nursing-creep area have been used with some success. Rubber mats and outdoor carpet are examples. Important considerations here are durability and ease of sanitation.

Some paints or plastic-like materials painted on the floor in the nursing area of the farrowing crate may aid in reducing knee and hock abrasions to the pig. A latex based cement may be obtained in most paint or hardware stores that may be applied over existing floor areas that are too rough or smooth. Only material that is non-toxic to the pig should be used. It is also wise to try these types of materials in a limited number of crates before committing the entire building. Some products of this type may result in a floor that is excessively slick. A liquid adhesive painted to the pigs' knees shortly after farrowing has been reported to have some effectiveness in protecting tissue in this area for a period of one week to ten days.

Summary

Decisions on what type of slat material to use should be based upon: cost, durability, freedom from maintenance, walking ease for the pig, self-cleaning and sanitation characteristics. It is generally conceded that good quality concrete slats are the most durable and the least expensive. Concrete slats also function extremely well for most phases of the life cycle.



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Building Materials and Equipment for Swine Facilities

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Producers who have invested in new swine facilities are often disappointed by the severe deterioration of their facilities after just a few years of use. Much of the deterioration could have been prevented if the producer had taken into account—during planning and selection of materials for the new facility—the corrosiveness of the environment within the facility and the pigs' destructive nature. These problems are generally more pronounced when pigs are crowded in confinement facilities but can occur in all types of units. The greatest and most rapid deterioration takes place near the floor because of wetness, chemical corrosion and physical destruction, but the effects of a corrosive environment can also be observed elsewhere within the building, especially on unprotected metal. The latter point is particularly characteristic of facilities with a poorly designed ventilation system (See *Pork Industry Handbook* Fact Sheets on ventilation.)

When planning your building, select materials that are corrosion-resistant and durable enough to withstand the rugged pushing, rubbing and chewing activities of the pigs. Materials within the building but outside the pens are not as vulnerable to physical deterioration, such as caused by chewing, but can have a relatively short life because of corrosion. If alleys are to be used for hog movement, the materials along the alleys will be subjected to some physical abuse from the pigs besides that resulting from moving equipment along the alleyways. Consequently, care is necessary in selecting equipment and materials regardless of their intended use or location.

Floors

Manure acids corrode concrete. Thus, a good, high-quality concrete mix is necessary. As a minimum, solid floors should be made from a mix which will yield a 3,500-psi concrete (maximum of 5 gal. of water per bag of cement). It is also recommended that air entrained concrete be used for all installations where the concrete will be subjected to freezing temperatures. For further protection, the concrete can be coated with a more corrosion-

resistant material such as Agri-500® or Duratuff®. Another alternative is to place a lower strength, less expensive concrete as a base and then add a higher strength concrete over the top as a wear surface. This approach can work quite satisfactorily where a layer of concrete is placed and rough graded, then a steel reinforcement mesh is placed, and, finally, a finish layer of concrete. The savings in material cost should be evaluated in light of possible inconvenience during placement of the concrete and/or higher labor costs.

If other floor finishes such as slats are to be used, they should be designed for corrosion resistance as well as strength. Where rubber mats are used, as in a farrowing facility, it is generally best to select a style with rubber lugs on the back. The mats should be placed in the fresh concrete and worked enough to assure full contact on the back. Additional flooring design details can be found in *Pork Industry Handbook* Fact Sheet 10, entitled "Swine Farrowing Units."

Walls

Concrete and wood-frame are both satisfactory for exterior walls. A choice should be made after considering both first cost and maintenance costs when exposed to normal conditions expected within the facility. Consider also the work required to provide openings in the wall, such as for ventilation.

Concrete is one of the most durable materials for use in walls that are subjected to animal and equipment contact. However, concrete has little thermal insulating value. Where warm interior temperatures are to be maintained, as for a farrowing or nursery facility, additional insulation is recommended. In cold climates additional insulation is desirable also in growing/finishing buildings to retain animal heat. In milder climates, concrete walls without insulation are satisfactory for some phases of a hog production installation.

Sandwich panel construction has been found to be an effective means of providing a durable interior and exterior

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surface and, at the same time, improving the thermal efficiency of the wall. Sandwich panels are formed by placing a foam board insulation material within the wall during casting of the concrete. This can be done either with cast-in-place walls or precast, tilt-up panels.

Another alternative which can be used where animals do not have access to the outside of the building is to erect a concrete wall and apply a spray-on urethane insulation material on the outside. In such cases, the insulation must be painted or otherwise protected to retard destruction by ultraviolet light from the sun. As with all foam insulation materials, a fire risk is involved with this technique. The risk, however, is reduced because the insulation is outside of a concrete wall. For added protection and still lower risk, the foam can be covered with ¼-in. layer of spray-on plaster or gunite concrete. The result is a durable, thermally efficient, stucco-like wall.

Wood-frame walls may be of either conventional stud frame or pole construction. In either case, where animals do not have access to the wall, a wide range of materials is available for enclosing the frame. Among the materials which have been used successfully are ribbed steel or aluminum, composition boards such as particle board or hardboard, plywood and boards. As with the basic wall construction, both initial and maintenance costs, as well as useful life, should be considered in deciding on the material to use.

With either type wall—stud or pole—thermal insulation can be added easily so long as appropriate construction plans are followed, such as planning stud or girt spacings to accommodate standard widths of insulation materials. As with exterior coverings, the range of insulation materials is broad and includes fiberglass blankets, pour insulation, foam boards and spray-on foams. Regardless of the insulation material chosen, an interior protective covering is necessary.

Where walls are exposed to personnel only and will not be subjected to hog contact or vehicular traffic, the choice of interior covering materials would include the same materials as for exterior surfaces plus such materials as asbestos-cement board. The brittleness of asbestos-cement board makes a solid sheathing underlying it necessary.

The potential for both vehicular traffic and animal contact at some time during the life of a facility makes the use of the more durable interior coverings desirable. For occasional contact such as along alleys used for hog movement, ribbed sheet metals, plywood, wood boards and composition boards are good choices. For continual contact, as in pens, the use of solid coverings—hardwood, steel sheets or panels, or fiberglass-impregnated plastics such as Glasboard® or Kemply®—is recommended. Work at Iowa State University indicated that porcelain-on-steel and stainless steel panels also effectively withstand corrosion and abrasion. Some aluminum alloys show promise of providing the desired characteristics.

On wall areas above the reach of the animals (usually considered to be about 4 ft.), most common building materials can be used. However, since sanitation is important in a swine building, these lining materials should be nonporous and durable enough to withstand cleaning with water discharged from a high-pressure cleaning system.

Ceilings

The main requirements for a ceiling material are cleanability and corrosion resistance. Like wall sections above the hog contact areas, most common building materials can be used. Although they are somewhat limited in their ability to withstand washing with a high-pressure cleaning system, vinyl-clad insulation boards have been used successfully.

Since roof trusses are usually spaced 4 ft. on center, the cost of any additional nailers required for installation of a particular ceiling product should also be considered as part of the ceiling cost. Materials such as ribbed metal can be attached directly to truss chords without additional nailers.

Insulation and Vapor Barriers

Where insulation is to be used, select it by considering not only its purchase price but also its installation cost, required coverings, and thermal effectiveness. In measuring thermal effectiveness, it is recommended that insulation or "R" values as given by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) be used (see Table 1).

The high moisture levels and the related high vapor pressures in swine facilities require that appropriate vapor barriers be used. These are needed to reduce the movement of water vapor through a wall or ceiling. Allowing water vapor to move into a wall will result in condensation within the wall or ceiling assembly. The condensation will result in a reduction of thermal efficiency and possible destruction of the insulation material. In general, a plastic (polyethylene) vapor barrier should be used with all insulation materials for, even with vinyl-clad foam boards, it is impossible to maintain all joints in a water vapor-tight condition. In all cases the vapor barrier should be located on the warm side (inside) of the wall or ceiling just outside or behind the interior covering.

Figure 1 illustrates the procedures for determination of the R value for a concrete block wall using the data in Table 1. Figure 2 shows how to calculate the R value of a ceiling.

Figure 3 indicates in a general way the insulation zones in the United States. An insulation value of R=14 in walls and R=23 in ceilings is suggested for heated buildings in a cold zone. Values can be lower in the mild zone but should be no lower than R=9 in the walls and R=12 in the ceiling. In all cases, local weather records and standard construction practices for similar facilities should be considered.

Mice and other rodents can seriously damage insulation and appear to be impartial as to the type of insulation material they destroy. If ribbed metal is used for inside wall linings, the end openings of the ribs should be closed to discourage the entrance of rodents. A good rodent control program is essential since they seem to find any small openings into the wall cavities. It is also important to recognize that birds are attracted to many types of spray-on insulation materials. Field experience has shown that birds, like rodents, are not partial to a particular insulation material. In some cases insulation is consumed directly as food, while in other cases it is used as a nesting location, a material for nest building at a remote location, or simply something to play with to pass the time. Consequently, an effective bird control program should also be a part of the building plan.

Pen Partitions

Pen partitions must be durable enough to resist rubbing, chewing and pushing by pigs, and, at the same time, to resist the corrosion of the environment and manure that comes into contact with them. The choice of materials depends partially on whether open or solid partitions are used and whether the partition is permanent or must be movable. Partitions are generally not insulated.

The durability and general corrosion resistance of concrete makes it an excellent choice for partitions (minimum of 2500 psi—7 gal. water per bag of cement—concrete is recommended). Concrete blocks, cast-in-

Table 1. "R" values and water vapor transmission characteristics for selected materials.

Material	"R" value per		Water vapor transmission	
	1-in. thickness	Thickness noted	Permeability* (perm-inch)	Permeance† (perms)
Fiberglass	3.5 approx.		116	
Rockwool	3.30		116	
Vermiculite	2.27		---	
Polystyrene	3.57-5.6		1.2	
Urethane	6.25		0.4-1.6	
Urea-tripolymer foams	4.48		16	
Urea-formaldehyde foams	5.0		32-38	
Fiberboard sheathing	2.5			
4" concrete masonry		0.71		
8" concrete masonry lightweight		2.00		
8" concrete masonry		1.11		2.4
12" concrete masonry lightweight		2.27		
12" concrete masonry		1.28		
4" CIP or precast concrete		0.32	3.2	
6" CIP or precast concrete		0.48	3.2	
8" CIP or precast concrete		0.64	3.2	
1/4" plywood (exterior glue)		0.31		0.7
1/2" plywood		0.62		
Hardwoods	0.91			
Softwoods	1.25			
Particleboard (medium density)	1.06			
1/8" hardboard:				
standard		0.17		11.0
tempered		0.12		5.0
1/8" cement asbestos board		0.03		0.54
Polyethylene:				
4 mil				0.08
6 mil				0.06
8 mil				0.04
10 mil				0.03
Single pane glass		0.04		
Double pane welded glass		0.87		
Single pane with storm window		0.94		
Air film:				
Outside, 15 mph wind		0.17		
Inside, still		0.68		
Inside, moving, due to ventilation inlets		0.17		
Air space:				
3/4"		0.87	120	
4"		0.95	120	

*Permeability is the rate of moisture movement through an inch of the material.

†Permeance is the rate of moisture movement through the thickness noted.

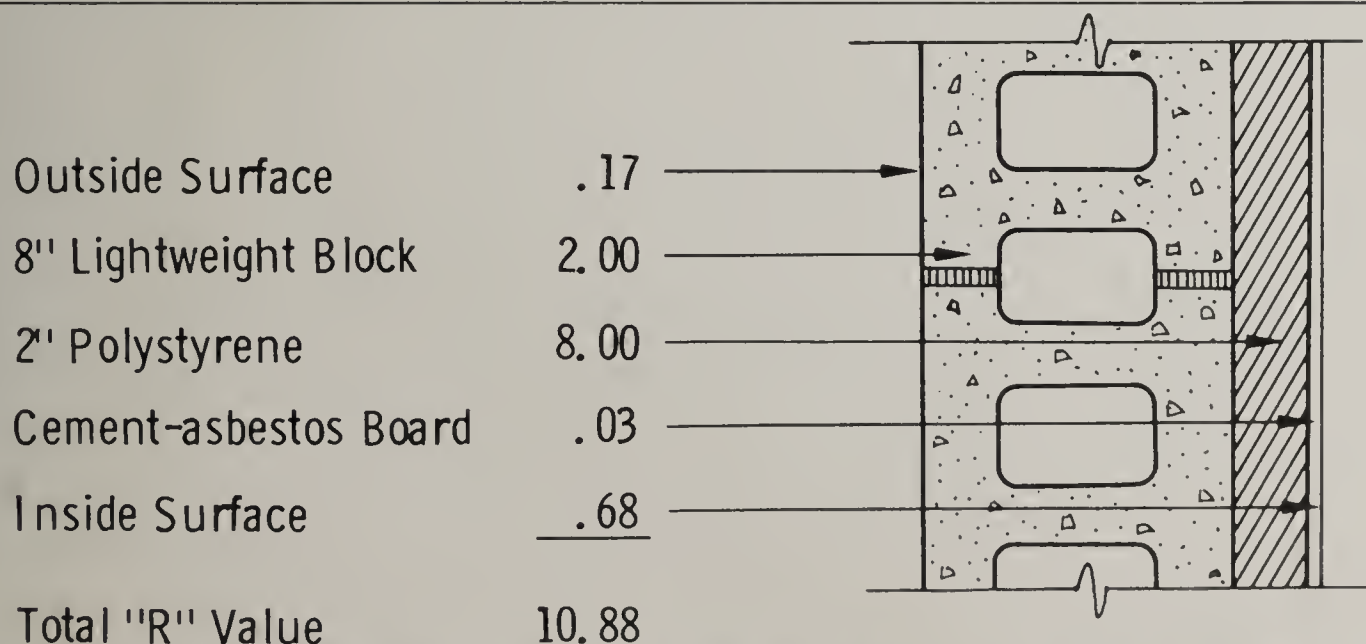


Figure 1. Insulated masonry wall. Omitting polystyrene foam insulation would reduce insulation R value to 2.88. This masonry block wall with only the cores filled with vermiculite provides a total R of 5.88.

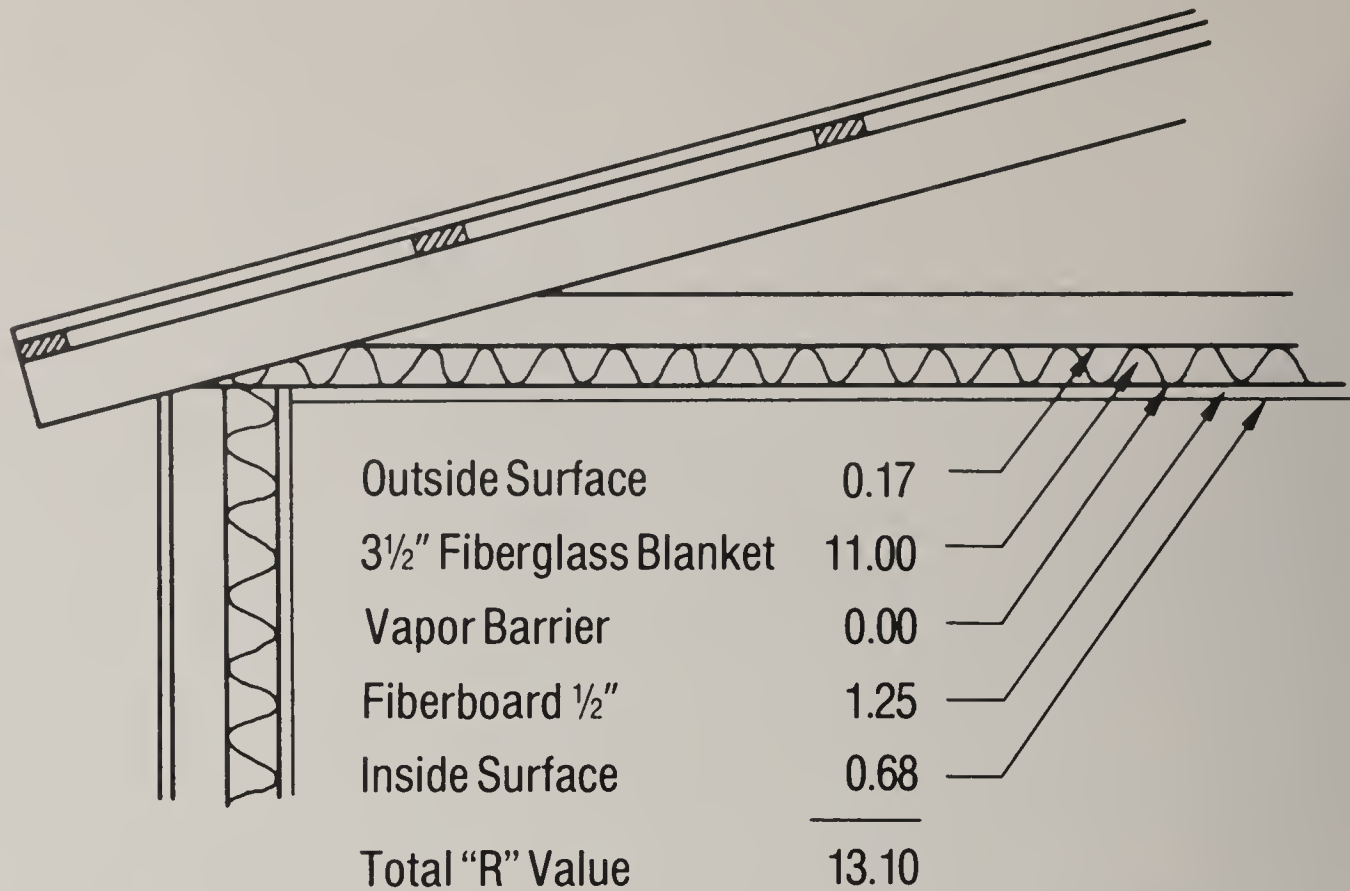


Figure 2. Insulated wood frame ceiling. Reducing the insulation to 1½ in. of fiberglass blanket reduces the ceiling R to 7.35. Changing ½ in. fiberboard (1.25 R) to ½ in. plywood (.62 R) and using only 6 in. of rockwool insulation (19.80 R) increases the ceiling R to 21.27.



Figure 3. insulation zones.



Figure 4. Concrete block partitions on the solid portion of the floor with open gates over the slats.

place concrete or precast concrete panels can be used (Fig. 4). As with exterior walls, steel reinforcing bars or mesh should be a part of all concrete partitions to afford greater strength and to fasten partitions securely to the floor. Where a partition must be movable or where an open partition is used, precast concrete "rails" have been satisfactorily used.

Some woods such as oak and southern yellow pine have lasted fairly well when used as pen partitions. A key requirement with wood is to assure that pigs are restricted from getting started chewing. This can be achieved by using tongue-and-grooved planks or wall-matched planks to reduce access to edges where chewing can start. Softwoods will probably have a useful life of 2 years or less. Hence, their use should be restricted to temporary shelters. As with exterior walls, the life of partitions can be extended by overlaying the basic wood partition with such materials as fiberglass-reinforced plastics, steel sheets or mesh. Where wood is in contact with the floor, ground or generally wet conditions, the use of pressure preservative-treated lumber is recommended for a longer useful life.

Both solid steel sheets and open welded wire mesh have been used successfully for pen partitions. The most common steel panels use vertical rods or tubing. The life of these materials depends on how well they can resist corrosion and flexing due to pushing by the pigs. To reduce the maintenance of partitions and the incidence of damage to pigs, all joints must be securely welded and protected from corrosion. Plain steel panels can be fairly satisfactory if well protected by a long-lasting coating. Unfortunately, the abrasive action of hogs wears away rather rapidly most post-installation coatings such as paint or epoxy. Also, once corrosion starts, it tends to work under the remaining coating and lift it away. Hence, the use of hot-dipped galvanized or porcelain coatings is recommended on all metal surfaces accessible to the pigs. Stainless steel is more expensive but might be worth the additional cost in permanent structures subjected to intensive use.

Roof Coverings

The most common covering materials used are plain or painted ribbed aluminum or galvanized steel sheets and asphalt shingles. The use of corrugated asphalt materials such as Onduline® is also increasing for both wall and roof coverings. All of these are satisfactory if good quality materials are purchased and properly applied.

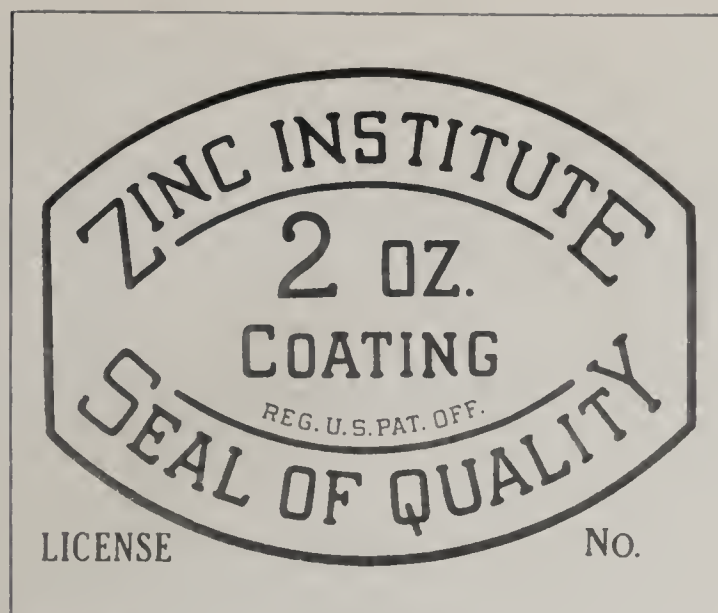


Figure 5. Zinc Institute grade stamp.

With galvanized steel, the use of sheets bearing a Zinc Institute, Inc. grade stamp is recommended. Exposure studies at The Pennsylvania State University revealed that sheets with a 2-oz. zinc coating (Fig. 5) and a "Seal of Quality" grade stamp required 15 years of exposure before the first signs of rust. Sheets with a 1.25-oz. zinc coating began to rust after 7 years. Sheets with less zinc per square foot than these industry standards are available at a lower cost and will have a correspondingly shorter life before the first signs of rust. It is not possible to determine the amount of zinc coating by visual inspection. Even where baked-on enamel finishes are used, the heavier zinc coatings should be used.

Bear in mind that galvanized steel is sold on the basis of thickness or gage. Gages most commonly available are 28 and 29. Lower gage numbers indicate greater thickness. Success has been good with both gages. A choice should include consideration of required roof design loads in the area and the load-carrying capacity of the roofing sheets. Manufacturers' literature and local codes can provide the required information.

In selecting aluminum roofing sheetings, the ease of installation should be considered. The use of high-strength alloy sheets of less thickness might be a disadvantage since their greater brittleness tends to cause them to split rather than dent if hit too hard or stepped on improperly.

Avoid the use of extremely long sheets because of changes in length with variations in temperature. This results in tearing out of nail holes or bending or extraction of nails or other fasteners. Fewer roof leakage problems are generally experienced where the length of roofing sheets is kept at 24 ft. or less. To prevent corrosion of metal roofing through galvanic action, it is imperative that the correct kind of fasteners be used with each kind of metal and that galvanized and aluminum sheets not be placed in contact with each other. Where it is necessary to mix galvanized and aluminum products, they should be separated by a non-metallic intermediate material.

If fiberglass-reinforced plastic sheets are to be used for light, care should be exercised during installation to assure a good seal. A bead of good quality sealant, such as polyurethane or silicone, should be run around all sides and all holes should be pre-drilled to reduce splitting. Except on very wide buildings—over 60 ft.—it is recommended that such skylights be eliminated from the roof and placed in the sidewall instead. On buildings over 60 ft. wide, a combination of sidewall translucent panels and skylights near the ridge of the roof should be used. Another alternative is to use translucent panels to enclose the ends of the building.

The use of at least 235-lb. asphalt shingles is recommended for all permanent structures. Self-sealing tabs are a good investment.

Regardless of the roofing material used, the limitations of its use as related to roof slope should be recognized. Table 2 lists recommended minimum roof slopes for several common roofing materials.

Table 2. Minimum recommended roof slopes for selected roofing materials.

Material	Slope (minimum)
Ribbed metal	3:12
Asphalt shingles	4:12
Roll roofing	3:12
Double coverage roofing	1:12
Corrugated asphalt	3:12

Plumbing

Because of the corrosive atmosphere within swine facilities, metal pipe should be used with caution. Copper pipe usually has a short life when exposed in a swine building. If galvanized or black iron pipe is used, some type of coating should be applied at the threads since this part of the pipe is most subject to deterioration and failure. PVC or similar plastic pipe is probably the most suitable for a swine building environment.

In warm facilities, plumbing can be run overhead to reduce contact with animals and manure. Although overhead pipes can be used in cold buildings, such placement requires use of electrical heat tape and pipe insulation to prevent freezing. Consequently, in cold facilities the use of underground plumbing is recommended. Where pipes are brought to the surface, they can be run through a larger diameter plastic pipe to reduce corrosion and provide easier maintenance.

In cold facilities, built-in heating units are suggested where cup waterers are used. Nipple waterers generally do not require additional freeze protection beyond that provided on the pipe up the nipple. In all cases, a durable high-strength cover is required over pipe insulation and heat tape to reduce damage by pigs and reduce the potential of electrocution of pigs. Adequate grounding of all electrical equipment is an absolute MUST. Good-quality

waterers should be selected to reduce maintenance costs, extend the useful life of the waterers and reduce water usage and manure hauling costs resulting from leaking valves.

Electrical

This may be the most critical component of a swine building since corrosion can create conditions that increase the risk of fire and electrical shock. Electrical materials installed inside a swine building should be designed for damp or wet locations. Thin-wall metal conduit has a short life. Fittings, outlet boxes and switches not designed for waterproof locations may create an unsafe condition after several years. If conduit is used, it should be plastic. Type UF cable with waterproof fittings is another option. If at all possible, locate the entrance box in a dry annex or office room to avoid rapid corrosion. In cold climates, problems can be reduced if all conduit is installed within the warm part of the building. When conduit extends from the warm building up into the cold loft or attic, condensation can occur and the resulting moisture can move back to a fitting and cause corrosion or shorts. If a pressure ventilation system is used, be sure that no moist, corrosive air can be pushed into electrical boxes.

As noted in the discussion on plumbing, grounding of all electrical equipment is a MUST. This applies to all switches, receptacles and appliances since wet floors increase the continual threat of shock and possible electrocution of both personnel and animals.

Feeders

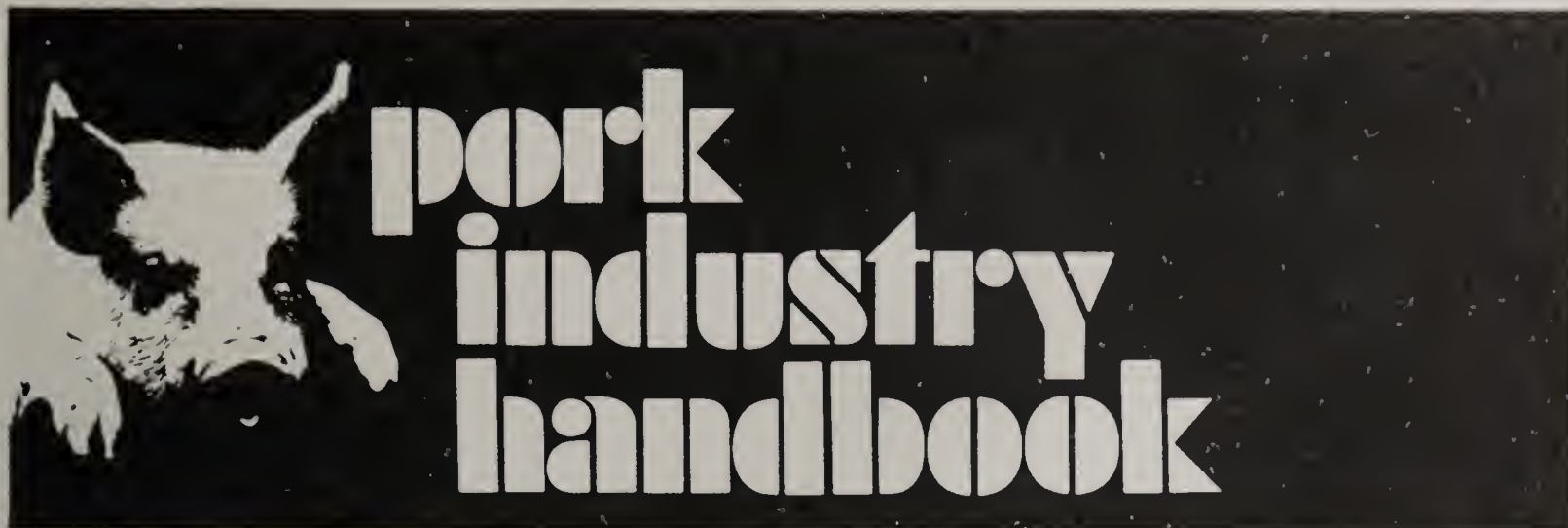
A low-quality feeder doesn't survive long in a hog house. The increased moisture level near the floor speeds up corrosion. The activity of the pigs causes rapid wear. The upper part of the feeder may last more than 10 years, but this helps little if the bottom has failed.

When purchasing a metal feeder, look for stainless steel or cast iron bottoms. Wood feeders are improved by covering the wooden trough with a more durable material such as fiberglass or metal.

As with plumbing and electrical lines, the running of feed conveyance equipment through a ceiling should be minimized to reduce the risk of moisture migration and the loss of heat.

Ease of adjustment in a feeder is as important as durability. If a feeder cannot be easily adjusted to prevent feed waste, it can easily cost its owner many times its replacement value.

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Mechanical Ventilation of Swine Buildings

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A well-designed and managed ventilation system is an essential part of any confined swine production building. Mechanical ventilation involves many factors, and these must be understood if the system is to be designed to function properly. It's a complete system of matched components—insulated building, supplemental heat, fans, inlets, controls, etc.—tailored to the environmental needs of the swine production building. Omitting any part of the team of components will result in unsatisfactory performance. For example, adding fans without providing adequate insulation will not provide the desired results.

Controlled ventilation will perform the following functions:

- Removes moisture, gases, odors, dust and air-borne disease organisms.
- Provides fresh air and distributes it uniformly without creating drafts.
- Modulates air flows according to needs so that temperatures can be controlled in winter and summer, assuming supplemental heating or cooling is available to handle temperature extremes.

Building Construction

Insulation in the walls and ceiling, and along the foundation and floor, is essential to keeping the building warm and preventing condensation. Using adequate amounts of insulation reduces heat losses and minimizes condensation in cold weather. Conserving heat in winter increases air temperature in the building, enabling the air to absorb and remove more moisture as it moves through the building's ventilation system. Insulation reduces solar heat gain in summer. Check other Pork Industry Handbook publications for information on this topic.

Unplanned openings such as cracks around doors, windows, and hog doors can nullify the benefits of a well-planned ventilation inlet system by changing the distribution and velocity patterns of air coming into the building. For this reason, mechanically ventilated swine buildings must

be tightly constructed. Many operators are eliminating windows to reduce this air infiltration and heat loss through the windows.

Ventilation Principles

During cold weather, the air flow requirements of a swine building are based on the moisture produced in the building and on the expected moisture content of the air entering and leaving the building. Figures 1 and 2 show the total moisture produced by hogs including the respired water vapor and the water evaporated from floors. The ventilation system is expected to remove this moisture and to maintain a relative humidity between 50 and 80 percent. Higher humidities may cause condensation and respiratory problems, while lower humidities may also cause respiratory problems.

During cold weather, the outside air entering the building contains very little moisture, as shown in Table 1.

Table 1. Moisture holding capacity of air at 100% relative humidity.

Temperature degrees F.	Grains* moisture/lb. dry air	Grains/ft. ³
-20	1.8	.16
-10	3.2	.28
0	5.5	.48
10	9.2	.78
20	15.1	1.25
30	24.2	1.95
40	36.5	2.88
50	53.6	4.12
60	77.6	5.82
70	110.7	8.09

* 7,000 grains of moisture equal one lb. moisture.

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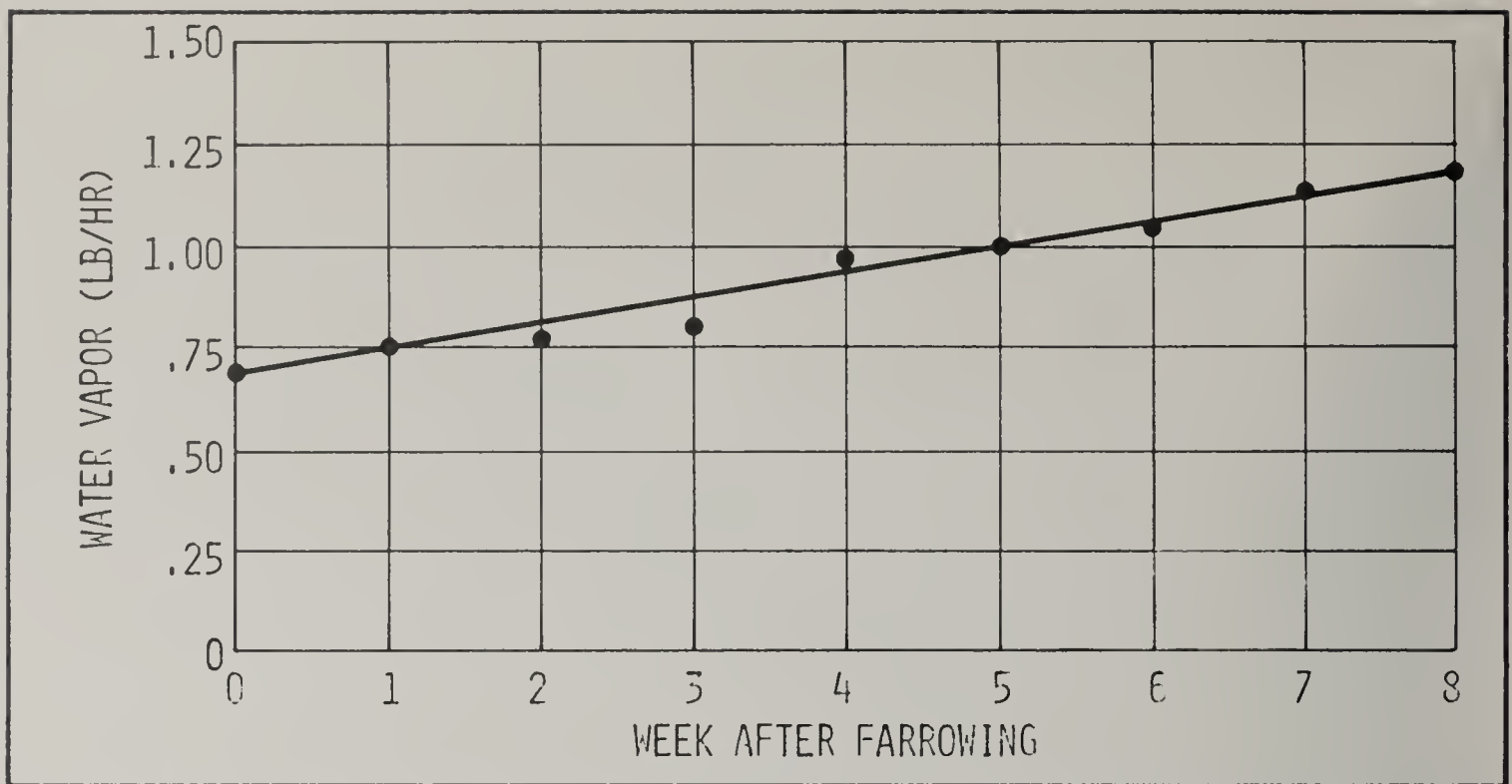


Figure 1. Moisture production, 340 lb. sow and litter at 80 F. Source: *Agricultural Engineers' Handbook—ASAE*.

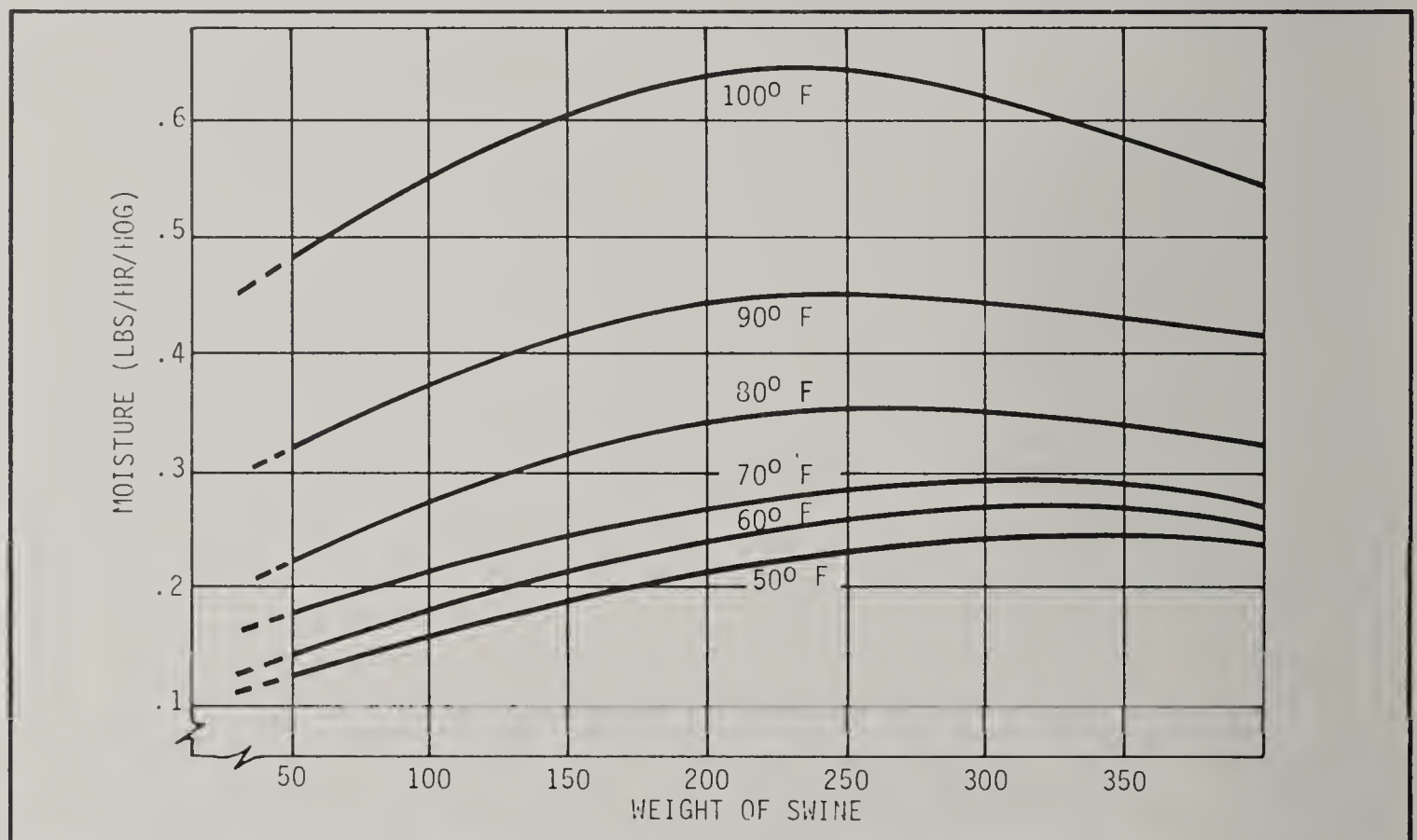


Figure 2. Moisture production of swine. Source: *Agricultural Engineers' Handbook—ASAE*.

When cold air is brought into an insulated warm building, the air temperature increases, which, in turn, increases its moisture-holding capacity. This warmed air picks up moisture and is then expelled by the fan(s). Figure 3 illustrates how expected inside and outside air conditions determine the ventilation rates for moisture removal. For example, at -20 F, a pound of air at 100% relative humidity contains 0.0003 lb. of water (2.1 grains) and occupies 11 cu. ft. If this air is warmed in a swine building to +60 F., this same pound of air expands to 13.3 cu. ft.; and if it is exhausted at this temperature and 75% relative humidity, it will contain 0.00831 lb. of water (58.2 grains). Every cubic

foot, then, will remove $0.00831 - 0.0003 \div 13.3 = 0.0006$ lb. of water. A 120-lb. hog produces 0.19 lb. of water per hour (Figure 2). Our ventilation rate for moisture removal for these conditions would be $0.19 \text{ lb./hr./pig} \div (0.0006 \text{ lb./ft}^3 \times 60 \text{ min./hr.}) = 5.3 \text{ cu. ft. per min. for each 120 lb. hog.}$

Because moisture removal is critical during extremely cold weather, the minimum winter ventilation rate is determined by the rate of moisture production in the building. If a rate higher than this calculated value is used, an increased heating bill should be expected. Table 2 gives the recommended rates for minimum, normal, and summer ventilation.

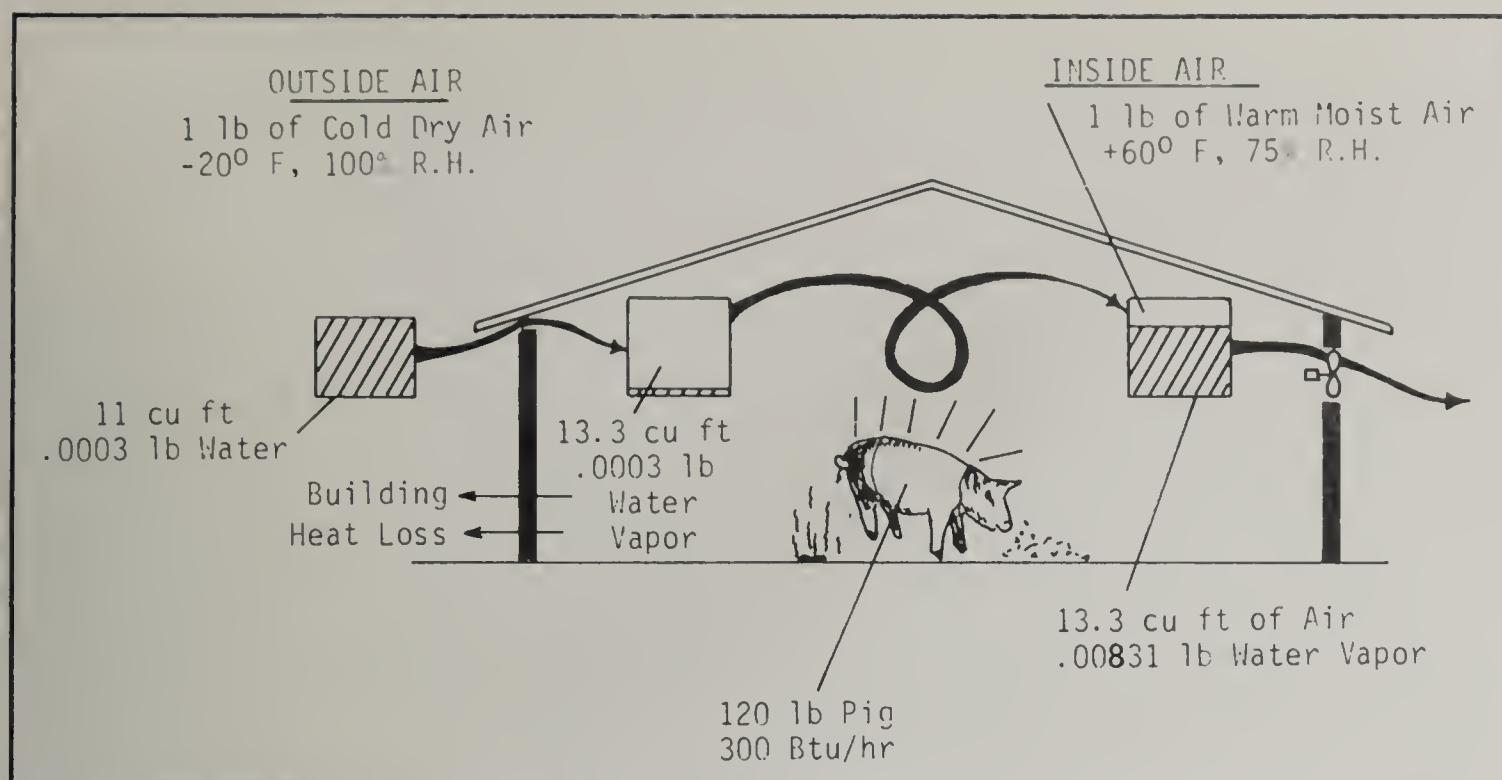


Figure 3. Winter ventilation in a controlled environment. Source: MWPS-1, *Midwest Plan Service Structures and Environment Handbook*.

Table 2. Recommended fan capacities (at ½ in. static pressure) per pig or sow and litter.

		Ventilation rates, cfm				
		Winter		Summer		
		Minimum (continuous)	Add Maxi- + mum†	Add + Total†		
Sow and litter	2-20	20*	(+60) 80	(+130)	210	
Growing pigs††	20-40	2	(+13) 15	(+21)	36	
	40-100	5	(+15) 20	(+28)	48	
	100-150	7	(+18) 25	(+47)	72	
	150-210	10	(+25) 35	(+65)	100	
Gilt, sow or boar	200-250	10	(+25) 35	(+85)	120	
	250-300	12	(+28) 40	(+140)	180	
	300-500	15	(+30) 45	(+205)	250	

*10 cfm continuous, 10 cfm on manual switch to control odor and humidity (may be shut off to save heat).

† Rates are cumulative totals, winter "maximum" includes "minimum," "summer" includes "winter." Example: Total winter rate for sow and litter is 80 cfm (not 80 + 20 minimum) of which 20 (or 10 and 10) is continuous. Total summer rate is 210 cfm of which the 80 cfm for winter is a part.

†† If totally slotted floors are used for growing pigs, the minimum continuous ventilation rate can be reduced to ½ the values listed.

"Minimum" Winter: Operate at least one fan at all times that the inside temperature is above 35 F. Set a thermostat to shut the fan off when the inside temperature drops below 35 F. This fan should supply the cfm rate listed under "minimum" in the table. Install this fan to exhaust the air from above any stored liquid manure.

"Maximum" Winter: Provide additional fans, thermostatically set to start in 5 degree steps from lowest desired temperature to prevent sudden drops in temperature. These fans, together with the minimum fans, provide the capacity for outdoor temperatures up to about 55 F.

Summer: Provide additional fans to supply the cfm rates listed under "Summer" in Table 2, or install large panels in the walls that can be opened for natural ventilation. Some or all of these fans or panels should be operated when the inside building temperature is above 75 F.

Types of Ventilation Systems

The two general types of mechanical ventilation systems are (1) positive pressure and (2) negative pressure (exhaust). Either system will work satisfactorily if designed, installed and operated properly.

Positive pressure systems use fans to force fresh air into the building and to distribute it by the use of lateral ducts or tubes with carefully designed outlet holes. Most positive pressure systems in use today are basically pressurized intakes, with sidewall exhaust fans to expel moisture, heat, odors and gases from the building as needed. Fan capacities in the exhaust portion of the system are sized as per Table 2 and are controlled by thermostats. A circulation fan (usually mounted near the ceiling and away from the wall) keeps the air flowing continuously through the duct or tube. The motorized wall intake shutters at the fan locations, which are controlled by the same thermostat(s) which controls the exhaust fan, open automatically bringing in fresh air from either the outside or from the loft above the ceiling. When the thermostat turns the exhaust fan off, the motorized intake shutters also close, and the fan simply circulates room air through the distribution duct or tube. Unit heaters can also be incorporated into this system, resulting in rapid and uniform distribution of heat throughout the building. Figure 4 illustrates a positive pressure intake ventilation system. This system is usually a commercially-available package which includes air circulation, heat distribution and ventilation. The system can function properly only if patterned and selected for a particular building.

Negative pressure, or exhaust, ventilation systems use a fan (or fans) to draw the air from the building, creating a negative pressure. Make-up air is drawn into the building through designed air intakes. As with any ventilation system, the incoming air must be well-distributed, properly mixed or blended so that it can remove moisture and/or heat, and do it without creating drafts. Figure 5 illustrates a negative pressure system.

Fan Systems Fan Capacities

Ventilation air requirements vary from the minimum cold weather capacity to many times this value in hot weather. Continuously-operating fans that exceed the minimum rate for moisture removal in cold weather waste heat. During the hottest weather, fan capacity is increased

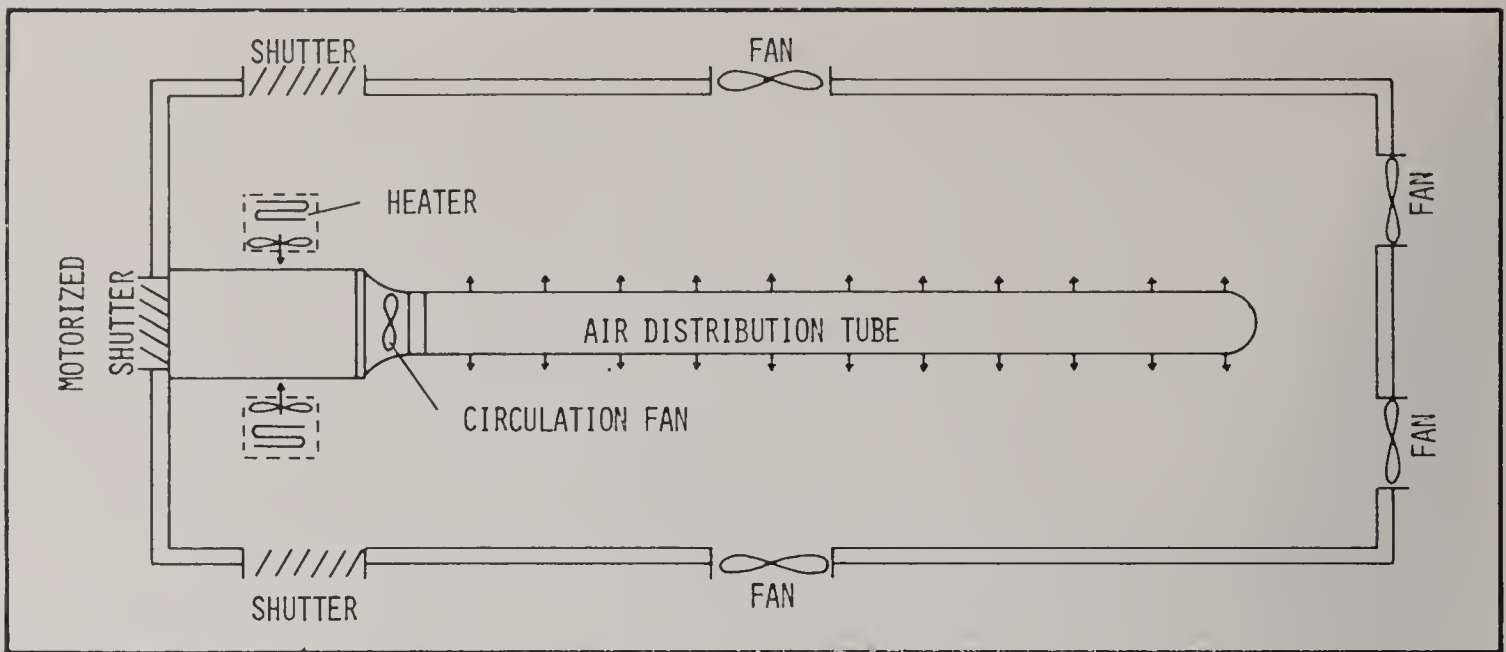


Figure 4. Positive pressure intake and air distribution.

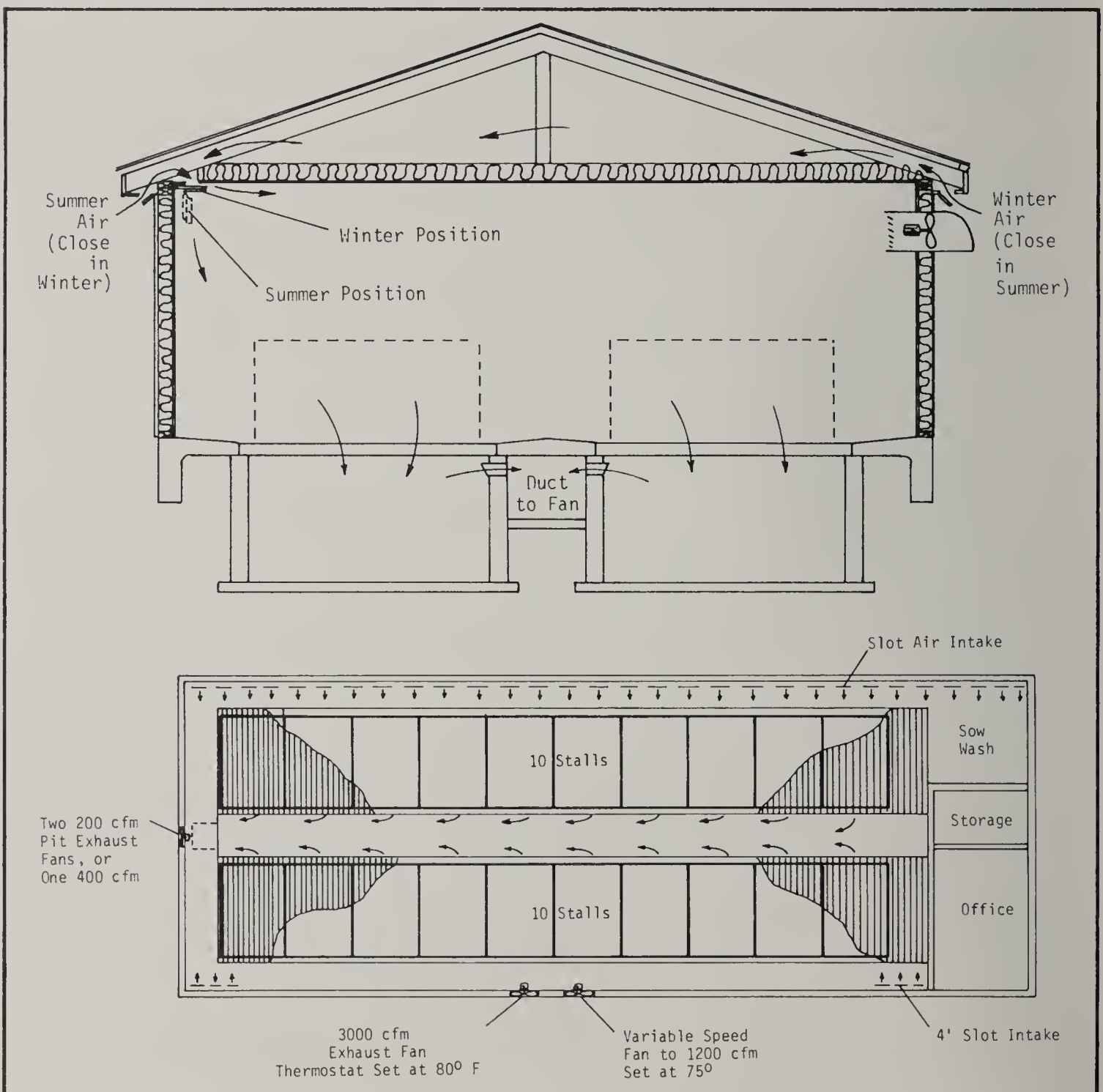


Figure 5. One type of negative pressure (exhaust) ventilation system with pit ventilation.

to the maximum rates to remove as much heat as possible and to provide good air movement around the hogs. To prevent rapid temperature changes, it is desirable to increase or decrease ventilation rates in several small increments rather than in one large increment. The range of air capacities in the ventilation system can be provided in various ways: (1) A small continuously-operating fan with "minimum" capacity plus larger fans, controlled in increments by thermostats which engage fans as temperatures increase or disengage them as temperatures decrease. (2) A single-speed fan controlled by a percentage or 10-minute interval timer allows a wide range of capacities, but is an "on-off" operation which may cause rapid temperature fluctuations and back-drafting at the intakes. (3) A single-speed fan with a motorized shutter or damper which restricts the output of the fan has been used successfully (the thermostat controls the motorized shutter which, in turn, controls the output of the fan). Sometimes one shutter is removed or shutters are partially blocked open so that a small airflow is always maintained. (4) Variable-speed fans automatically proportion air flow from a minimum of about 20% of their full-speed rated capacity. Such fans are modulated by a solid-state control which regulates the voltage going to the capacitor-start, capacitor-run motor. Care should be taken to protect the fan from outside wind pressure when operating at low speed as it does not produce much pressure and will greatly affect air flows.

The capacity of a fan to move air is expressed in cubic feet per minute (cfm). In a well-planned ventilation system, it is essential to know the exact amount of air that a particular fan will move under the expected operating conditions, or the ventilation system will not operate as designed. If the fan (or fans) moves more or less air than specified, inlet velocities will be different, and conditions in the building will probably not be satisfactory. If the fan capacity is too great, excessive heat losses will occur, wasting energy and dropping temperatures below desirable levels. If capacity is too low, a build-up of moisture, odors or heat can be expected.

Ventilation systems for swine buildings are usually designed for static pressures of $\frac{1}{8}$ -in. static pressure to assure good operating characteristics. If there are several fans in the system, this $\frac{1}{8}$ -in. rating is especially important to assure that one or more fans is not "outpulling" others and causing air to go backward through the fan. Not only do fans need to operate against the negative pressure at the intakes, but such accessories as shutters, fan guards and hoods offer some resistance and collectively may increase the static-pressure to $\frac{1}{8}$ -in. water gage. The Air Moving and Control Association (AMCA) has set up standard tests and procedures. Certified AMCA performance charts and fan ratings will assure the operator that the fan will deliver the volume of air specified for the static pressure and with accessories in place as listed or shown.

Fan motors should be:

- Totally enclosed for dust protection.
- Able to operate continuously.
- Of the sealed ball bearing type, preferably.
- Equipped with thermal overload protection.
- Wired with separate circuits.

Air Intakes

The fan, or fans, in a mechanical ventilation system determines the rate of air change, but the uniformity of air distribution depends on the location, design and adjustment of the air intakes in exhaust systems or of the air outlets in pressure systems. It is especially important to maintain enough inlet velocity in winter so that cold air is mixed or blended with the warm air. Ideally, the opening or cross-sectional area of air intake should be based on the capacity of the fans. If the intake area is too great, cold air enters at

low velocity, causing it to "dribble" in, settling to the floor and causing drafts.

Air intakes should be designed and constructed so that a negative pressure of 0.03 - 0.07 in. of water gage is created at the inlet (see Figure 6). This will assure velocities of between 700 and 1100 ft. per min. A common rule of thumb sizes intakes at 1 sq. ft. for each 600 cfm of fan capacity, which makes the velocity about 1000 ft. per min. including the vena-contracta effect (the reduction in effective cross-section of an opening through which air flows). Table 3 will give the rate of air flow through 1-ft. long ventilation-slots.

Table 3. Rate of air flow through ventilation slots one foot long, including the vena-contracta effect.*

Inches slot width	cfm Static pressure	
	0.04 in.	0.125 in.
1	50	100
2	100	200
3	150	300
4	200	400

*Source: Pennsylvania State University

Example: A 20-sow farrowing house is ventilated in winter with a variable speed fan having minimum capacity of 320 cfm at low speed and 1600 cfm at high speed. What size should the slot inlets be?

Assume a 1 in. slot width. From Table 3, each foot of 1 in. slot will admit air at the rate of 50 cfm at 0.04 water gage. Therefore, the slot needed will be $1600 \text{ cfm} \div 50 \text{ cfm/ft} = 32 \text{ ft. long}$. Unless the slot is adjustable, the velocity at low volume would be: $320 \div [(32 \times 12) \div 144] = 120 \text{ ft. per min.}$ This velocity would be minimal to maintain good distribution and blending of the intake air. This installation balance between fan capacities and inlet area requires air intake control to adjust the area of intake to the capacity of the fans that are operating. An intake system that adjusts the opening area automatically, according to negative pressure sensed, is ideal for exhaust systems.

The necessary adjustments to provide the optimum air distribution at the various air flow rates must be understood by the individual operator. The methods which are used vary and will work if properly installed and operated. They include:

1. Separate inlets for winter and summer. This allows air to be drawn from the loft in winter and directly from the outside in summer, Figure 7.
2. Gravity-loaded curtain or damper at the intake, Figure 8.
3. Manually-adjustable hinged or vertically-adjustable baffles under ceiling slot intakes.
4. Power-operated adjustable baffles under ceiling slot intakes.

Other important considerations in planning fresh air intakes include:

1. Make sure there are no unplanned openings or holes that will interfere with the planned air intake system. All openings, including doors, windows, hay chutes, cracks around doors, etc., should be closed.
2. Provide insulated baffles under the intake slots or holes to direct the air. In winter, the incoming air is directed across the ceiling where it is warmed and mixed with the warmest air in the building. This also prevents heavier cold air from dropping or settling to the floor where it could cause drafts and, in turn, chill pigs. In summer, the baffle can be used to direct the air to the floor.
3. Bringing winter air through the attic reduces the effect of wind and allows the air to be tempered somewhat before it enters the swine housing area. This can be accomplished by slot inlets under the eaves or by screened

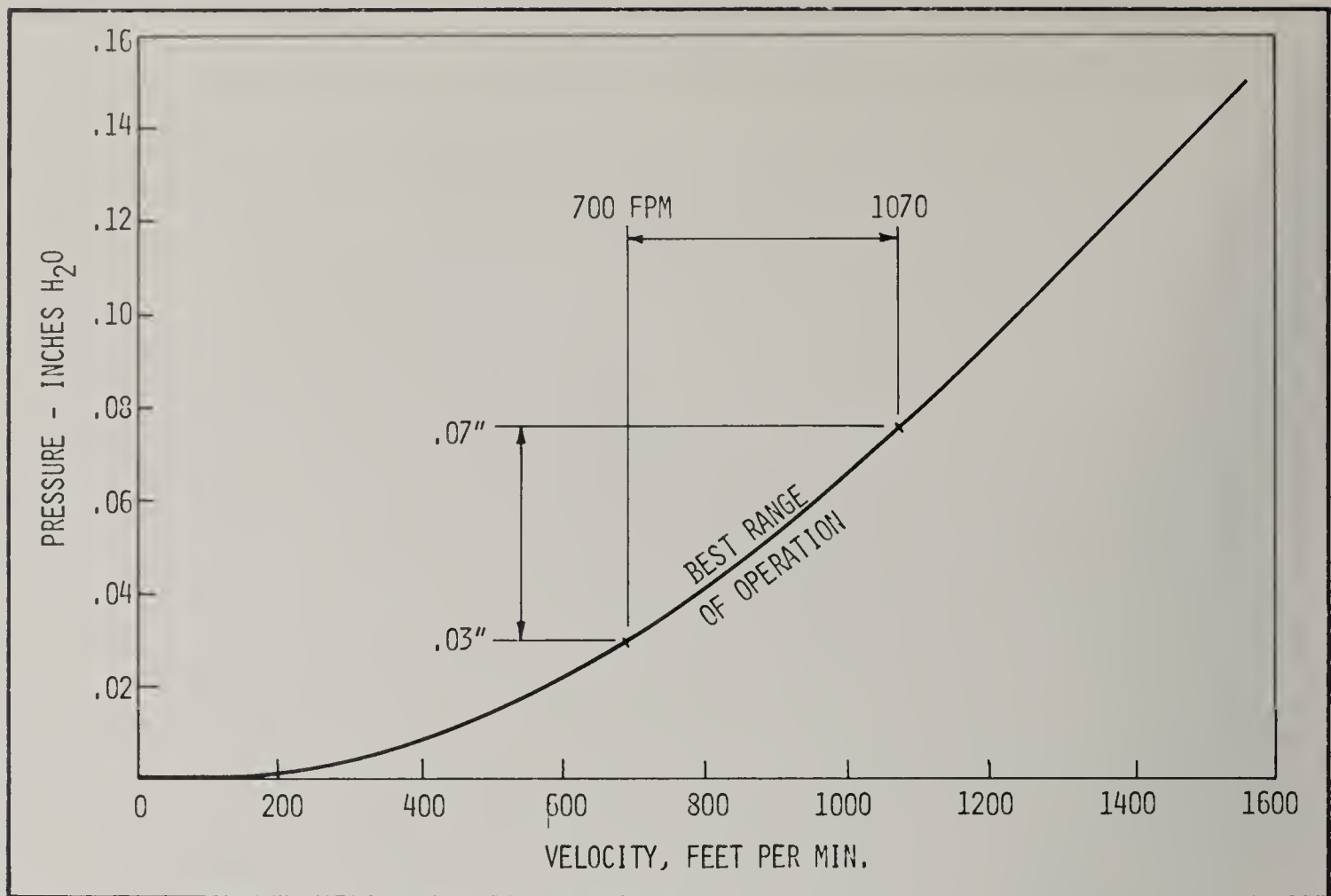


Figure 6. Air intake velocity and static pressure relationship.

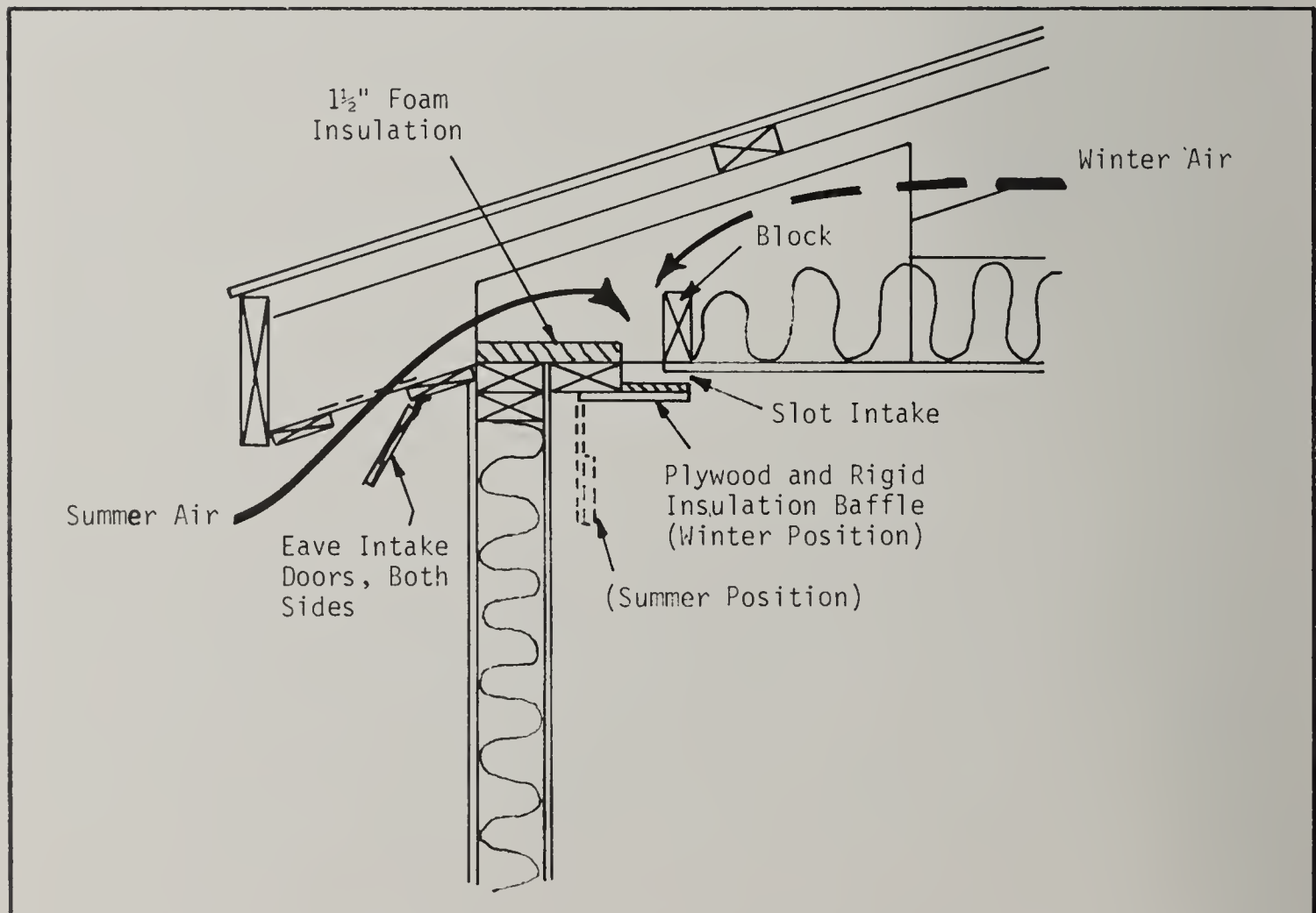


Figure 7. Typical eave and baffled slot intake. Source: Midwest Plan Service.

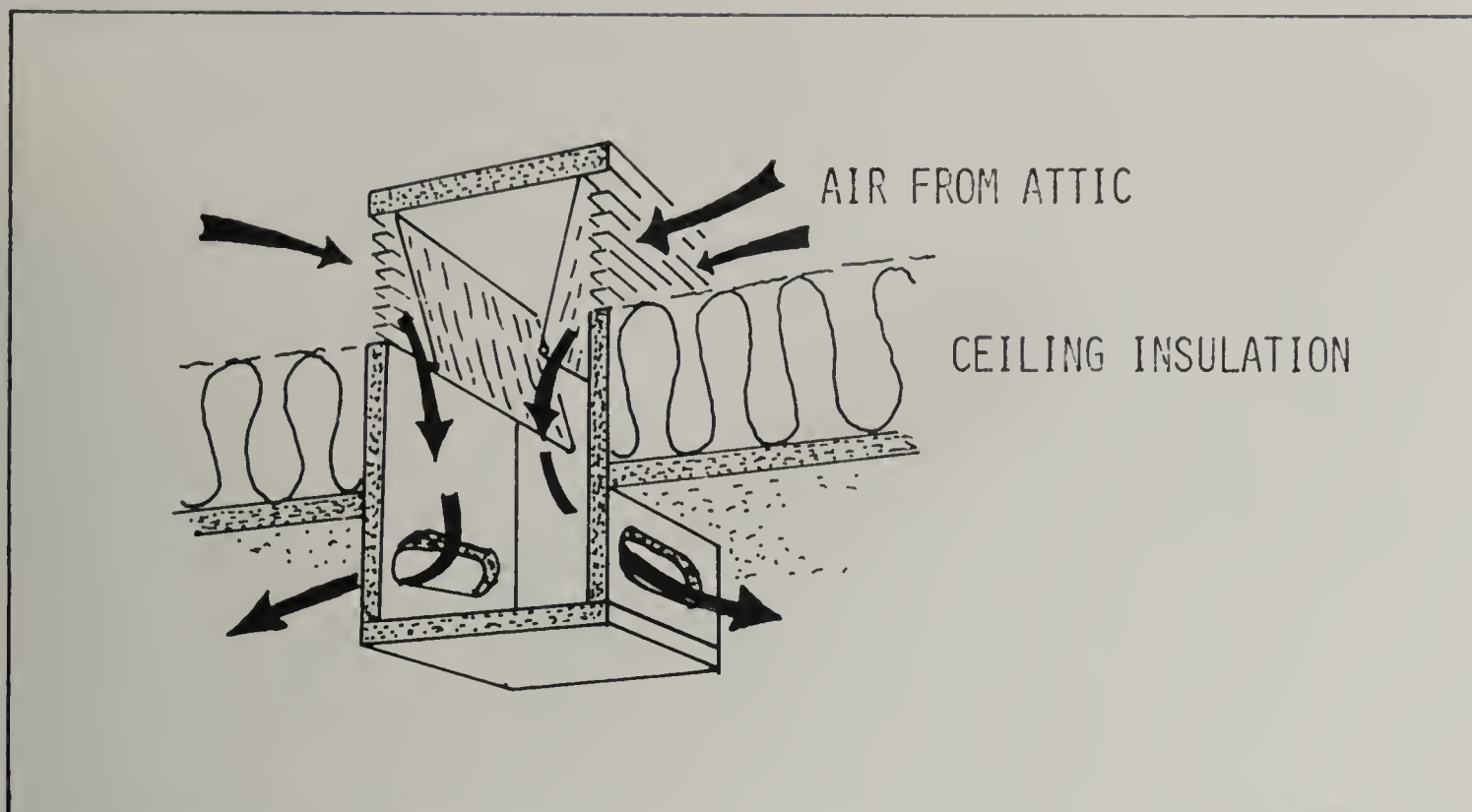


Figure 8. Rectangular ceiling area intake with self-adjusting damper.

louvers at the gable ends. The air intakes from the outside to the attic should have a net free area of $1\frac{1}{2}$ - 2 sq. ft. for every 1,000 cfm of fan capacity.

Controls

Good accurate sensing controls are necessary for the satisfactory and automatic operation of a ventilation system.

The most common control has been the line thermostat which contains a temperature-sensing element and a switch. The sensing element is usually a bi-metallic strip which expands or contracts to activate a switch which opens or closes the electrical circuit to the fan motor or motorized shutter. The thermostat is a relatively simple, economical and reliable control. However, it is important to use a good quality thermostat designed especially for livestock buildings. It should also respond rapidly to temperature changes and have accuracy to within a few degrees.

Humidistats, which have an element sensitive to the moisture content of the air, are usually not recommended as a fan control device in livestock buildings since dust accumulations on the sensing element greatly affect their accuracy.

Ten-minute interval timers, sometimes called percentage timers, are often used in conjunction with thermostats to provide minimum ventilation rates even though the building temperature may be lower than the thermostat setting. Interval timers are adjustable to operate any desired percentage of time, such as two minutes out of ten, or 20% of the time.

The control for the newer variable-speed fans consists of a solid-state electronic speed control and a thermistor heat sensor. The control regulates the voltage to the fan motor, reducing voltage and fan speed as temperature in the swine building declines, and increasing voltage and fan speed as the temperature increases. At the temperature setting on the control, the fan will be operating at about one-half capacity. It reaches maximum speed at about 4 F. above the setting and minimum speed at about 4 F. below the setting. A safety thermostat should be incorporated with the variable-speed control to turn the fan off completely when the temperature declines below the minimum to be maintained in the building. This could occur if the supplemental heater fails or has insufficient capacity.

Locate controls where they will sense the average normal conditions in the room being ventilated. Never locate controls on outside walls or where they may be affected by sunlight, drafts from air intakes, heating devices or other abnormal conditions. Accuracy of temperature-sensing controls can be checked with a thermometer located next to the control. Controls should be located out of reach of animals but where the operator can easily read the temperature setting and adjust it. The controls may be grouped in a bank in a convenient location.

Maintenance of the System

Good quality fans, inlets and controls do not require a lot of attention. However, regular scheduled maintenance will provide more efficient performance and longer life of the equipment. Periodic cleaning, lubrication and adjustment will assure reliable performance of the system. Further information is available in PiH-41, "Maintenance and Operation of Ventilation Fans for Hog Barns" and in MWPS-8, "Swine Housing and Equipment Handbook."

Information on installing a warning system or emergency ventilation when the power fails is available from equipment suppliers, power suppliers and State University Extension Agricultural Engineers.

Rust and corrosion are inherent problems in confinement swine ventilation equipment. Some manufacturers have developed and are producing fiberglass housings for their fans (see Figure 9). Others are using stainless steel for the fan frames and hoods, and some are using special protective coatings to prevent rusting and corrosion. Keeping the fan, housing, hood, shutters, etc., clean and performing regular maintenance will minimize deterioration and increase the performance and life of the equipment.

Under Slat Ventilation

In swine buildings with liquid manure stored in pits below slotted floors, ventilation of the space between the liquid manure and the slats is recommended. The "minimum" continuous winter fan (or fans) is located to exhaust air from the pit to aid in removing gases and odors. Warmer slat floors and less convective drafts are also benefits of under slat ventilation.

An exhaust duct, installed under the slats or along side the manure pit walls with properly sized and spaced open-

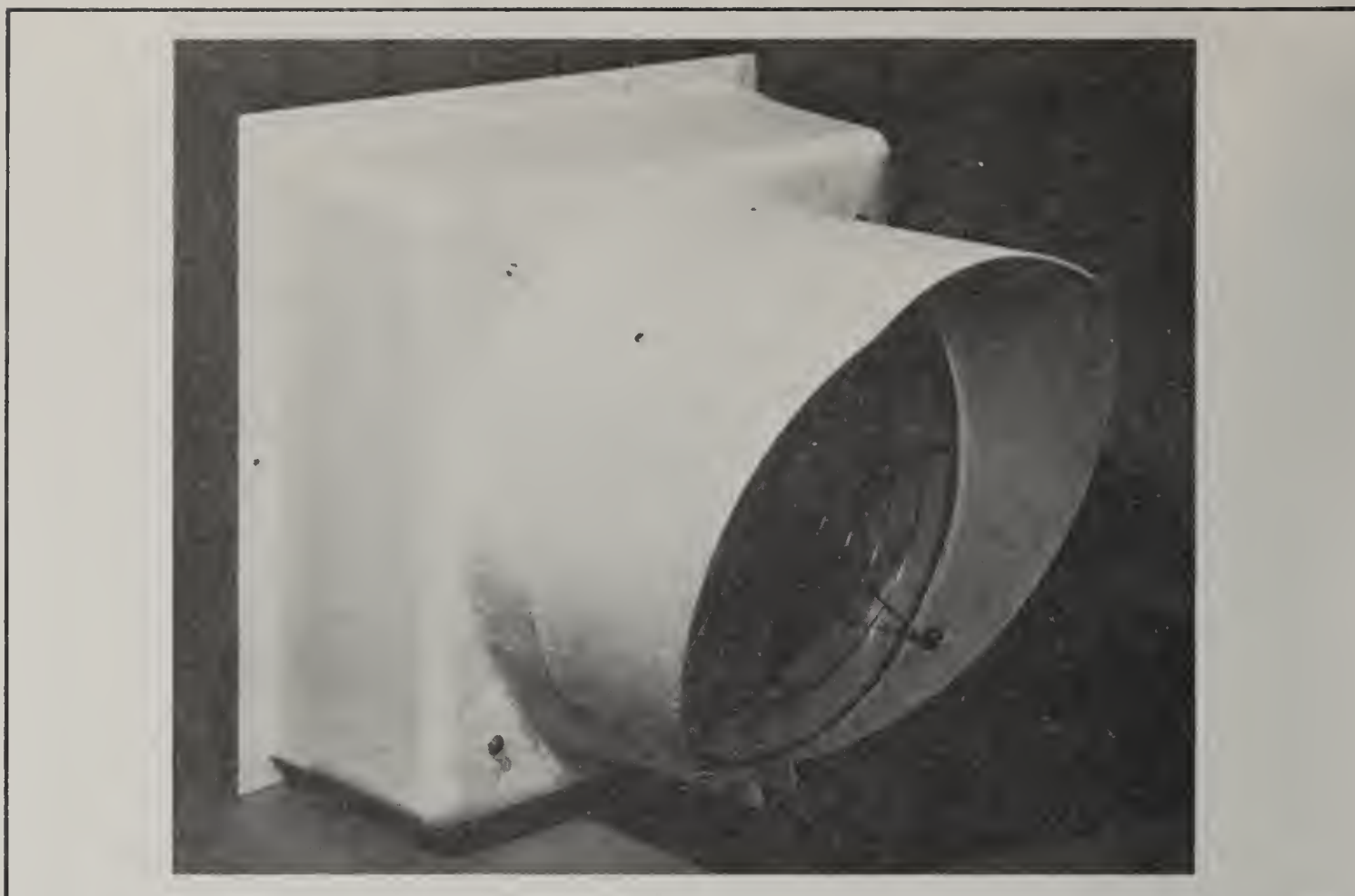


Figure 9. Materials used for fan housings and hoods, such as fiberglass, stainless steel, and special surface treatments on steel, are more resistant to corrosion and rust than ordinary painted or galvanized steel. They still require periodic cleaning, however, to operate effectively.

ings to the manure pit, will aid in collecting the air uniformly for the full length of the pit. An exhaust fan with the "minimum" ventilation capacity then expels the exhaust air from the duct (see Figure 5).

To reduce the negative pressure against the exhaust fan, the duct should be sized so that the maximum air velocity is approximately 600 ft. per min. The equation below can be used to determine the size of the duct.

$$A = \frac{Q}{V}$$

Where Q = quantity of air in cubic feet per minute.
 V = air velocity in feet per minute.
 A = area of duct in square feet.

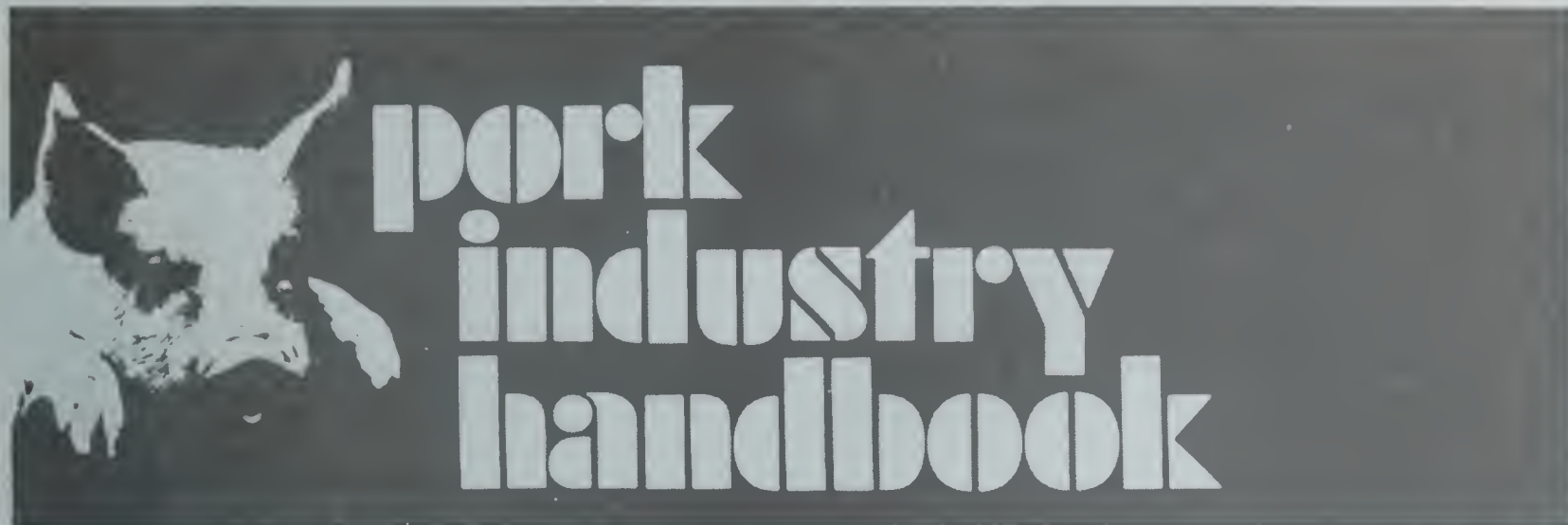
Properly sized and spaced openings from the pit to the duct allow the exhaust air to flow through each opening from the pit into the duct. Opening size and spacing must be designed if reasonable distribution is to be obtained. The size of these openings is determined by allowing an entry velocity of 800 ft. per min. through each opening.

Operator Checklist

1. Fan capacities should modulate or adjust to provide the range of air movement needed for the various conditions in the swine building throughout the year.

2. Select fans according to their capacity at ½-in. static pressure to assure rated delivery even though other fans are operating in the system.
3. Install and adjust inlets to maintain good distribution of fresh air without causing drafts.
4. Ventilation system should be at winter "minimum" level before supplemental space heat is added to the building. Heating and ventilating system controls should be coordinated to prevent unnecessary heat removal by the ventilation fans.
5. Consider planning the ventilation system for adaptation of solar heat at a future date. For example, orient the building east and west to provide a good solar collector area for heating incoming ventilation air.
6. Set up a regular ventilation equipment maintenance schedule.
7. Keep all fan information and warranties in a separate file. Complete packaged systems should have an "owner's and operator's manual."

Reference to products in this publication is not intended to be an endorsement to the exclusion of others which may be similar. Persons using such products assume responsibility for their use in accordance with current directions of the manufacturer.



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Internal Parasites of Swine: Natural History and Control

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It is well known and accepted that swine are damaged by many kinds of internal parasites (worms). Considerable financial loss results from retarded growth and the failure to convert feed efficiently, from increased susceptibility to other diseases and from organ and carcass condemnations.

These parasites or worms are the same all over the United States. There is no climatic barrier to parasitism. The most prevalent worm is the "large round worm," *Ascaris suum*; the next most prevalent is the nodular worm. These are followed by whipworms and stomach worms. Two types of lungworms are found throughout the U.S. Threadworms (*Strongyloides*) probably parasitize every pig. In some parts of the South the large kidney worm is prevalent. All of these worms are roundworms.

In the last 20 years worms that use beetles as intermediate hosts—certain stomach worms (roundworms) and the thornyheaded worm—have declined in the Midwest.

Natural History and Chronology

The swine breeding herd has its own population of internal worms, and these survive for months and years in the external environment, on the pastures and in lots, in the farrowing houses and gestation facilities. Older animals do not become immune to worm infection; rather, they redevelop parasitisms semiannually as they go back and forth from the farrowing house to their pastures and lots. Although sows and gilts have larger populations of nodular and stomach worms, it is a mistake to believe that they do not have large roundworms (*Ascaris suum*) and whipworms. Older animals (sows) have more kidney worms than gilts.

There is little evidence of prenatal worm infection in pigs. There is transcolostral transmission (in first milk) of the tiny little threadworm, *Strongyloides*. A pig's first exposure to worms is to the infective larvae of *Strongyloides* in colostrum. This has been reported widely in the southeastern U.S. Second possible exposure to

worms occurs when pigs eat *Ascaris* (the large roundworm) eggs, and/or stomach and nodular worm larvae in old manure from sows, found in and around the farrowing crates and pens where pigs spend the first three or four weeks of their lives. Newly weaned pigs eat more infective *Ascaris* and whipworm eggs in the manure which may be present in the nursery or growing-finishing lots or pens.

There is a universal prevalence of worms in 20-30 lb. pigs. Usually the first *Ascaris* (large roundworm) infection in pigs is the largest one. This is followed by the major whipworm parasitisms. In some sections of the U.S., whipworms cause mortalities in pigs weighing less than 20 lb. When pigs reach 70-90 lb. there is a rise in the numbers of nodular worms and stomach worms.

Many pigs now are grown to 35-40 lb. with only a few *Ascaris* (large roundworms) or no worms at all, but when they are put into growing pens or dirt lots they encounter overwhelming exposures. The large roundworm (*Ascaris*) population increases along with that of the whipworm, the nodular worm, and the stomach worms. Weaned pigs placed on dirt lots for finishing rapidly acquire considerable populations of five or six different kinds of worms. Permanent pasture lots are where lungworms persist in their intermediate hosts, earthworms. Pigs have almost no ability to resist worm parasitisms until they are well past 100 lb.

Infective stages of worms are resistant to all kinds of weather conditions and external environments—where they are eaten by pigs. There are enormous populations of infective *Ascaris* (large roundworm) and whipworm eggs, and infective larvae of nodular and stomach worm larvae, on swine lots and pastures. Few swine herds are free of parasitisms.

Rationale for Treatment and Eventual Control

There is a widespread and unfortunate misimpression that worm parasitisms are similar to infectious diseases. Historically, much effort has been directed toward enabling

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individual animals to survive parasitisms and achieve the "immune states." Swine do not achieve an immune state and become free of parasites.

Consider worms similar to the weeds which grow each year and affect plant production. Both weeds and worms have incredible ability to survive in the external environment. Both weeds and worms have annual populations, and the sows and gilts undergo parasitism as regularly as they undergo gestation. When pigs are weaned and dewormed, sows and gilts are turned out on the lots where infective stages of worms can be found year in and year out; they are reinfected. These new worms develop and flourish until sows go back into the farrowing facility where they generally are dewormed again. Deworming obviously is not complete because so much transmission of worms to young pigs occurs in the farrowing house. Failure to deworm sows and gilts completely is due to incorrect worming procedures; broad-spectrum dewormers ought to be used as the basis of treatment programs.

Sanitary procedures aid in the control of worms by removing the infective stages from the environment, but no sanitary measures are successful for more than a short time. Infective parasite eggs cling to dirty sows; so washing sows thoroughly prior to farrowing is a good practice. However, more worms are acquired by young pigs from eggs passed in manure by sows after they farrow.

Good feeding programs do not make swine resistant to worms. Better-fed animals are more desirable hosts for worms to grow up in, and the reproductive potential of worms is enhanced by the balanced rations which have more protein factors needed by worms in order to produce their eggs. However, poorly fed pigs are also very

susceptible to large worm infections because they are forced to compete so completely for anything resembling food.

Deworming with Chemicals

No one should retain the notion that swine should be treated as single animals. That approach has not reduced worm populations in the past. Treat herds. Treat boars, sows and gilts to improve performance and prevent transmission to pigs. Use treatments to attack the worm populations as they develop chronologically.

Use broad-spectrum dewormers instead of products that remove only one species such as *Ascaris*, the large roundworm, because parasitisms are comprised of a number of kinds of worms. Deworm animals on a *regular schedule* designed to eliminate the major parasite populations. Establish a deworming schedule and follow it.

Systematic treatments related to the chronology of parasitisms are shown in the table.

Life Cycle Deworming Program

Deworm boars, sows and gilts prior to breeding and prior to farrowing to prevent exposure of the young pigs. Use 1-day treatments or new continuous deworming programs for sows and gilts before they farrow, to keep sows and gilts in the farrowing house free of parasites and unable to transmit parasitisms.

To produce worm-free feeder pigs, feed an anthelmintic-antibiotic from 20 to 40 lb. or use two, separate, 1-day treatments at 25 and 35 lb. Deworm feeder pigs soon after arrival at the farm and again at 75 and 110 lb. weight, in single day dewormings. An alternative method uses the 30-day deworming program between 40 and 75 lb., followed by the single treatments at the heavier weights.

Table 1. Summary of the most prevalent internal parasites of swine, age group affected, effects on host and effective anthelmintics.

Parasites	Pigs in which major reproducing population is found	Specific ways in which parasites damage their hosts*	Effective anthelmintics†
Threadworm (<i>Strongyloides</i>)	10-20 days Suckling pigs Breeding stock	Causes moderate to severe to bloody diarrheas in very young pigs. Can result in mortalities.	Tramisol®
Large roundworm (<i>Ascaris suum</i>)	Weanlings, Feeder pigs, 40-75 lb, 110 lb, Gilts, Sows, Boars	Its migrating larvae damage liver and lungs and create conditions favorable for development of bacterial and viral pneumonias, cause diarrheas, occlude intestine. Generally <i>Ascaris suum</i> causes liver condemnations. Economic damage occurs in pigs.	Atgard®, Banminth®, Hygromix®, Piperazine®, Thibenzole®, Tramisol®
Whipworm (<i>Trichuris suis</i>)	15-20 lb 40-85 lb	Accumulations of whipworms ulcerate the caecum and anterior large intestine. They provoke bloody diarrheas.	Atgard®, Hygromix®
Nodular worm (<i>Oesophagostomum</i> spp.)	All ages, 60-350 lb (increases with age)	The host response results in nodule formation, which decreases digestive efficiency, and outright illness often results.	Atgard®, Banminth®, Hygromix®, Piperazine®, Tramisol®
Stomach worm (<i>Hyostrongylus rubidus</i>)	All ages, 60-350 lb	Irritates the lining of the stomach or tunnel beneath it and causes inflammation and ulceration. The end result can be diarrhea.	Atgard®
Lungworm (<i>Metastrongylus</i> spp.)	Generally feeder pigs & older 60-150 lb pigs on old lots	Irritates the fine air passages, ruptures tissues, causes bleeding, allows development of pneumonias.	Tramisol®
Kidney worm (<i>Stephanurus</i> spp.)	Generally older pigs & breeding stock	Damages liver, perirenal tissues, ureters, kidney.	No treatment cleared

* In terms of economics, parasites affect their hosts by interfering with digestion, feed conversion, and weight gains so that production is made more expensive.

† These systems of treatment were designed to fit into feeding programs. The fact that a certain dewormer is listed does not

necessarily mean that another will not do the same job. As a rule, the authors prefer broad-spectrum dewormers because the average parasitism has more than one kind of worm. Producers should be aware that excellent swine dewormers are now on the market (and more are on the way). Read and follow the directions on the labels very carefully.



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External Parasite Control

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External parasitism is a continuing problem for swine producers. Estimates of annual losses to louse and mange infestations range from \$10 million to \$50 million. Lice and mange mites can also mechanically transmit diseases such as swine pox and eperythrozoonosis. The major problems are caused by the hog louse—*Haematopinus suis*—and mange mites—*Sarcoptes scabiei* and *Demodex phylloides*.

Life Cycle of the Hog Louse

The hog louse (Figs. 1 and 2) is a blood-sucking parasite that feeds exclusively on the pig. It is a large ($\frac{1}{4}$ in. long) pest that clings to the hair of the neck, behind the ears

and in the folds of the skin. It can survive for 2-3 days off the pig in warm bedding, but it will not generally attack other species. The life cycle of the louse takes about 25-30 days to complete from adult-egg-adult. The adult life span is about 35 days. An adult female will lay 3-4 eggs daily for approximately 25 days. These eggs are attached to the hair shaft and hatch as nymphs (immature forms) in 12-20 days. Nymphs are similar in structure but smaller than the adult. The nymphs will go through three maturation stages to adulthood. During development, lice may feed in clumps, generally on the more tender areas of the skin. Hog louse infestation starts around the ear and expands to the lower body and then to soft-skinned abdominal areas. All stages

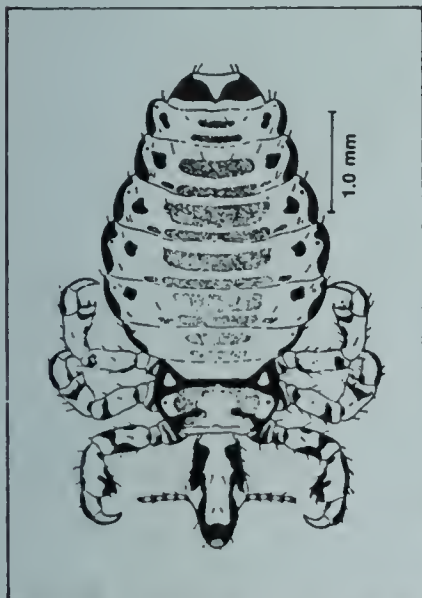


Figure 1, left. The hog louse is a bluish-black pest approximately $\frac{1}{4}$ in. long. It will be most readily observed on the necks of infested pigs. (From Whitehead, 1942. Used by permission from Diseases of Swine, 4th ed., ed. by Howard W. Dunne and Allen D. Lemmon © 1975 by the Iowa State University Press, Ames, Iowa 50010).

Figure 2, right. Lice may feed in clumps, generally on the more tender areas of the skin.

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of the life cycle occur on the skin surface. The pest does not burrow into the skin.

Symptoms

Mild louse infestations may cause no clinical problems. In more extensive infestations, the pests can be seen as dark bluish-black discolorations on the skin. The continuous sucking of blood and lymph causes irritation to the skin, leading to some itching. Damage from lice is primarily irritation, making the hogs restless and decreasing feed intake and growth rate in growing-finishing pigs. In addition, anemia may occur in young pigs because of the blood loss. Lice are also capable of mechanically carrying swine pox virus, *Eperythrozoon suis* and other diseases to susceptible pigs.

Life Cycle of Mange Mites

Mange mites of two types affect swine. *Sarcoptes scabiei* var. *suis* is the most common mite found on swine. *S. scabiei* burrows into the upper two-thirds of the dermis. Initial infestation generally begins in the inner ear and spreads over the head, along the neck and then across the body. The life cycle takes about 15-25 days to complete. New females, as they mature, mate close to the skin surface and then begin new tunnels for their young. This is the only external exposure during the life cycle. The adult female lays 1-3 eggs daily for about 15 days. These eggs hatch in tunnels at about 5-10 days and mature to adults in 10-15 days. The mature female dies approximately 30 days after reaching maturity.

Symptoms

Initially, the skin has small raised areas covered with brownish scabs. This is followed by hyperkeratosis--thickened, rough skin (Figs. 3 and 4). An intense itching may accompany the infestation, although in mild infestations itching may be negligible. The activity of the mites increases as skin temperature is elevated by fever or high environmental temperature. This increases the irritation and feeding rates and may intensify the itching in affected pigs. Probably the highest mite activity is found during the summer but creates less of a problem for producers because of less contact spread and better control ability. High winter populations probably reflect the difficulty of treatment during cold weather and more contact spread.

Infestations by *Demodex phylloides* are uncommon in swine. The mites live in the hair follicles and produce a pimple-like lesion. The complete life cycle is not known, but the mites require about 3 weeks to develop through 3 larval stages to the adult. Adults will live for 1-2 months. Initial infection begins around the nose and eyelids, then moves to the abdomen and inner thigh areas. No serious pruritus (itching) nor other clinical problem is involved with this parasite. Occasionally, the pimples become infected and an abscess develops.

Transmission

Mange mites and lice of hogs are generally found infesting only swine. The pests are not carried on other animals, so pig-to-pig contact is the major means of transmission. Hog lice and sarcoptic mites can live in warm bedding for several days or longer under ideal conditions before attaching to a new host. Occasionally, this will result in clean animals being infected without animal contact. Primary transmission, however, is by direct contact with infected pigs. Demodectic mites are very susceptible to drying and low temperatures and will live only a day or two away from the host.

Treatment

Successful treatment of lice and mange is a difficult assignment because it requires a complete break in the



Figure 3. Shown is a severe sarcoptic mange infestation in a mature pig. It is characterized by rough, thickened folds denuded of hair on the ear and neck regions.

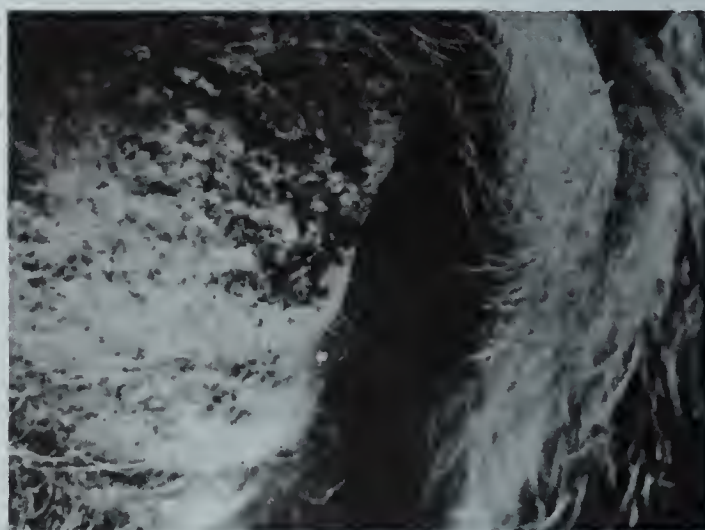


Figure 4. Close-up view of Sarcoptes-infested outer ear, showing thickened skin with scab formation.

parasite's life cycle. Because of the increased susceptibility of baby pigs to lice and mange and the increased toxicity of many chemicals to pigs under weaning age, the sow becomes a focal point for pest control measures.

Sows should be routinely sprayed for mange control 45 days prior to farrowing. An additional spraying at 30 days pre-farrowing may be needed for satisfactory control. The mange mites, because of their habit of burrowing deep into the skin and the tissue debris which results, are protected from many surface-applied products. High-pressure spraying (100-250 psi) to force insecticide into the tunnels and to cover the animal completely, particularly around the head and neck, with 2-4 qt. of finished spray is required. Because of the better coverage and penetration of approved insecticides--malathion, toxaphene and lindane--spray applications currently are most successful in mange control. Eradication of sarcoptic mites is extremely difficult under field conditions; however, routine spraying will keep the pest in check.

A successful sow pest control program should be followed by a maintenance program for the growing-finishing pig. Animals about 8 weeks of age should be sprayed with an approved insecticide. A follow-up spraying in 2 weeks is recommended for better control. Additional

applications can be made as needed to market weight provided withdrawal restrictions are followed.

If the sow pest control program has not been followed, mange infestation in suckling pigs can be reduced by applying malathion dust or Korlan® spray to the pigs. When they are more than 8 weeks of age, the control program listed above must be followed.

Successful louse control can be accomplished with all the products labeled for mange control. Additionally, CoRal®, Ciodrin®, Ciovap®, Korlan®, and Rabon® sprays, Tiguvon® pour-on and CoRal®, malathion and Rabon® dusts have been used successfully. Use of Korlan® granules or Rabon®, malathion, or CoRal® dust on bedding in conjunction with spray application may make the treatment more effective. Korlan® spray and malathion dusts can be used directly on the suckling pig for louse control. However, these treatments of the suckling pig are not routinely needed if a successful gestating-sow pest control program is carried out. For louse control on lactating swine, Tiguvon® 3% pour-on can be used without adversely affecting the suckling pig. No known treatment for demodectic mites is available. Infected animals should be removed from the herd to minimize further transmission.

Weather Influences

During severely cold weather, Korlan® granules and malathion, CoRal® or Rabon® dust as bedding treatments, or malathion or Rabon® as direct applications can be used for temporary louse control. Spray applications can be made during winter months by selecting sunny, calm days when the temperature is above freezing. Small portable, low-volume misting applicators can be used for good parasite control. Insecticides can be in an oil or water base with a small quantity (4-6 oz. per animal) applied. Because of the smaller volume, fewer problems of chilling are encountered during cold weather application.

Table 1 lists currently labeled products found successful in external parasite control. Products, use concentrations and approved uses may change periodically. You are encouraged to read and follow the product container label to insure safe and effective treatment.

Withdrawal periods must be carefully observed because of the residue-producing potentials of these chemicals. Read the label for information on withdrawal times, proper product usage, and application rates. Do not overtreat animals with any pesticide.

Table 1. External parasite control products.

Compound	Usage instructions	Sarcoptes	Demodex*	Lice	Withdrawal times (days)	Special instructions
Co-Ral® 25% w.p.	Mix 1 lb./50 gal. water			X	0	
Co-Ral® 1% dust	1 oz./head					
Ciodrin® 13.1% e.c.	3 1/3-8 1/3 pt./50 gal. water			X	0	
Korlan® 24E	Mix 2 qt./50 gal. water			X	0	Can be used on pigs less than 30 days old.
Korlan® 5% granules	Apply 1/2 lb./100 sq. ft. bedding			X	0	
Lindane 20% e.c.	Mix 1 pt./50 gal. water	X		X	30	Do not treat pigs before weaning.
Lindane 12.4%	Mix 1 1/2 pt./50 gal. water	X		X	30	
Malathion 4-5% dust	Apply 1/4-1/2 tbsp.	partial		X	0	Can be used on pigs less than 30 days old.
Malathion 57% e.c.	Mix 2 qt./50 gal. water	X		X	0	
Methoxychlor 24% e.c.	Mix 1 gal./50 gal. water			X	0	
Rabon® 50% w.p.	Mix 4 lb./50 gal. water			X	0	
Rabon® 3% dust	3-4 oz./head					
Tiguvon® 3% pour-on	0.5 fl. oz./100 lb. body wt.			X	14	May be used on gestating and lactating sows.
Toxaphene 60% e.c.	Mix 3 pt./50 gal. water	X		X	28	Do not treat pigs before weaning.

This table represents usage and withdrawal information as presented on current labels. Label changes can occur at any time. Before using any pesticide, read and follow the label directions.

The amended Federal Insecticide, Fungicide and Rodenticide Act of 1972 requires that all pesticides be classified for *general* or *restricted* use. Producers purchasing or using restricted-use pesticides after October 21, 1977, must become certified or additional state regulations may limit use of certain pesticides. Check with your state Extension specialists for certification or use requirements and for the specific latest control recommendations.

*There are no known treatments available for Demodex infections in swine.



pork industry handbook

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Atrophic Rhinitis

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History

Rhinitis is an inflammation of the mucous membranes that line the pig's nose. Atrophic rhinitis (AR) is a transmissible disease of swine that is characterized by both rhinitis and wasting away or lack of growth of the turbinate bones in the nose. The turbinate bones are small, scroll-like, mucous membrane-covered structures in each nostril. They condition the air by warming, moistening and filtering it during the inspiration phase of respiration.

Other forms of rhinitis include necrotic rhinitis (bull nose) and a virus disease, inclusion body rhinitis. These diseases cause inflammation without turbinate atrophy. This discussion will be limited to atrophic rhinitis.

There are extensive reports in the veterinary literature regarding atrophic rhinitis. The oldest of these reports date back to a German scientist's 1831 description of atrophic rhinitis. The disease was first described in the United States and Canada in 1942-43. It had undoubtedly existed on this continent much earlier.

Incidence

Atrophic rhinitis is widespread among the U.S. swine population. Various authors report that 25-75% of all slaughter swine have evidence of atrophic rhinitis. Herd incidence has been estimated at 40-90%.

Cause

A bacterium, *Bordetella bronchiseptica*, has been proved to be a widely distributed causative agent of AR in the U.S. Other bacteria, especially *Pasteurella*, may be involved as secondary invaders that intensify the disease. Irritating gases in the pig's environment and concurrent diseases such as diarrhea or chronic pneumonia have been suggested but not verified as factors causing intensification of atrophic rhinitis.

The problem is complicated by the fact that *B. bronchiseptica* can be carried in respiratory tracts of many mammals such as cats, dogs, mice, rats, and even man.

The following facts explain how *B. bronchiseptica* bacteria survive and infect pigs:

1. In a dry area exposed to the sun, most of the organisms will die in 5-6 weeks.
2. In a cool, shaded moist area, the organisms may survive up to 4 months.
3. All of the common disinfectants and fumigants are effective against the organism if they come in contact with it.
4. The organism lives and multiplies almost exclusively in the respiratory tract but is not confined to the respiratory tract of only swine. Control and eradication plans would be much more successful if *B. bronchiseptica* were exclusively an organism of swine.
5. It has been recovered from the respiratory tracts of a wide range of mammals including man, cats, dogs, rodents, and many others. It may occur with a much lower frequency in the respiratory tract of birds, but at present birds are not considered to have very much potential for spreading the disease.
6. The organism has been recovered from flies and ants. The possible insect spread of the infection must receive additional study.
7. Not all strains of the organism have equal disease-producing ability (virulence) for swine. There are as yet no practical laboratory tests to tell the degree of virulence of an individual strain of the organism for the pig, but it appears that many of the nonswine-origin strains may have low pathogenicity for pigs. Herds infected from nonswine sources frequently require a few years of pig-to-pig passage before turbinate damage becomes apparent. On the other hand some swine herds infected by the introduction of clinically infected pigs will have clinical disease in pigs farrowed within a few weeks of the introduction of the infected pigs.
8. SPF pigs inoculated with *B. bronchiseptica* at 1-11 days of age had advanced turbinate atrophy 3 weeks after inoculation. Comparison with noninfected litter mates

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followed to slaughter, however, showed that infection in this case did not result in the development of a lasting, growth-retarding form of atrophic rhinitis. This emphasizes the important role of secondary invaders and environmental management in the atrophic rhinitis complex.

Spread

Atrophic rhinitis is spread in three common ways.

1. By an infected shedder sow infecting her litter shortly after birth.
2. Through the air in farrowing houses and nurseries.
3. By exposure to nonswine sources such as cats.

Losses

It has been estimated that atrophic rhinitis causes a production loss of 5-10% in the average herd. Losses can be much higher than this when atrophic rhinitis becomes severe and is complicated by poor management. Mortality is low; the losses are mainly in slowed growth and poorer feed efficiency. Some production losses may occur in herds that have minimal clinical signs of the disease.

Clinical Signs

Clinical signs are those of a nasal infection. The signs vary with the strain of bacterium involved, secondary bacterial and viral invaders, health status and age of the pigs involved.

Sneezing is the most common sign. Sniffling, snorting and coughing are usually observed in pigs with atrophic rhinitis. A moist crescent-shaped area on the face below the eye caused by excessive tearing is commonly present.

A clear to yellowish-white discharge from the nostrils is frequently observed. This discharge may contain blood in severe cases. Twisting and/or shortening and thickening of the nose may occur. The shortening of the upper jaw may cause malalignment of the teeth. Pneumonias are common, and occasionally brain involvement may occur.

All ages of swine can become infected with *B. bronchiseptica*, but the most severe lesions require that the pig be infected during the first few weeks of life.

Environmental stresses such as overcrowding and cold, damp, drafty quarters can intensify a rhinitis problem. Other health problems such as diarrhea, pneumonias or parasitic infections also magnify the problem.

It cannot be overemphasized that the severity of atrophic rhinitis is frequently related to the level of management existing in the herd.

Diagnosis

Diagnosis is by clinical signs and by observing the turbinate atrophy during postmortem examination. The turbinates are examined by carefully sawing with a fine-toothed saw across the nose at the level of the second premolar tooth. The first premolar tooth erupts at about 1 year of age; therefore, the first visible jaw tooth in pigs younger than 1 year is the second premolar. Bacterial cultures of the nasal cavity may result in the isolation of *B. bronchiseptica*.

Control

Several methods are used to limit atrophic rhinitis. These are:

1. Cull visibly affected animals on a continual basis—a simple procedure but the least effective.
2. Use the "all-in all-out" system in the farrowing house and in the nursery rooms.
3. Maintain older breeding stock and keep the percentage of replacements to a minimum.

4. Isolate sows and their litters until after weaning. Continue to isolate each litter for 1 month after weaning. Select breeding stock from litters that are free of clinical signs and also react negatively to nasal swabbing tests for bordetella.

5. Caesarean-derive pigs, and rear in isolation—SPF procedure.

Bordetella can survive in the soil for several weeks. Six weeks in the summer and 3 months in the winter are considered to be the minimal "down time" necessary to repopulate a premise that was previously contaminated. It is strongly recommended that repopulation be done during the summer months.

To maintain a bordetella-free herd:

1. Quarantine the herd from exposure to other swine.
2. Use the closed herd concept.
3. Add only boars that have had 3 consecutive negative swabbing tests to bordetella with no positives, or add only SPF laboratory-derived pigs.
4. Control cat and rodent populations.
5. Monitor the herd by nasal swabbing and culturing a portion of each new crop of weaned pigs.

It has been reported that there are cyclic high and low populations of bordetella organisms, even when no treatments are being used.

Treatment

Treatment is based upon drugs that are secreted into the nasal cavity. The two drugs of choice that fit this category are sulfamethazine and sulfathiazole. Because these drugs work by blocking the nutrient intake of bacteria, treatment must take place over a considerable period to be effective. It is usually recommended that a sulfa level of 100 gm. per ton of feed be administered to sows for 3-5 weeks. This is done shortly before farrowing. Pigs receive the same level of sulfa in their feed for a 6-week or longer period starting at preweaning and continuing until the pigs reach 50-75 lb.

An alternative is to treat both the sows and pigs with the water-soluble form of sulfathiazole in the drinking water at the level of 1 lb./1,000 gal. Sows are treated for 3 weeks prior to farrowing until 1 or 2 weeks after farrowing. Baby pigs are offered medicated water from the first day of life until they reach 50-75 lb. Great care must be used to insure that sulfa-medicated feed or water is not fed to market-weight hogs unintentionally by contamination of their feed or water with sulfa-medicated feed or water. Always observe the recommended preslaughter withdrawal time.

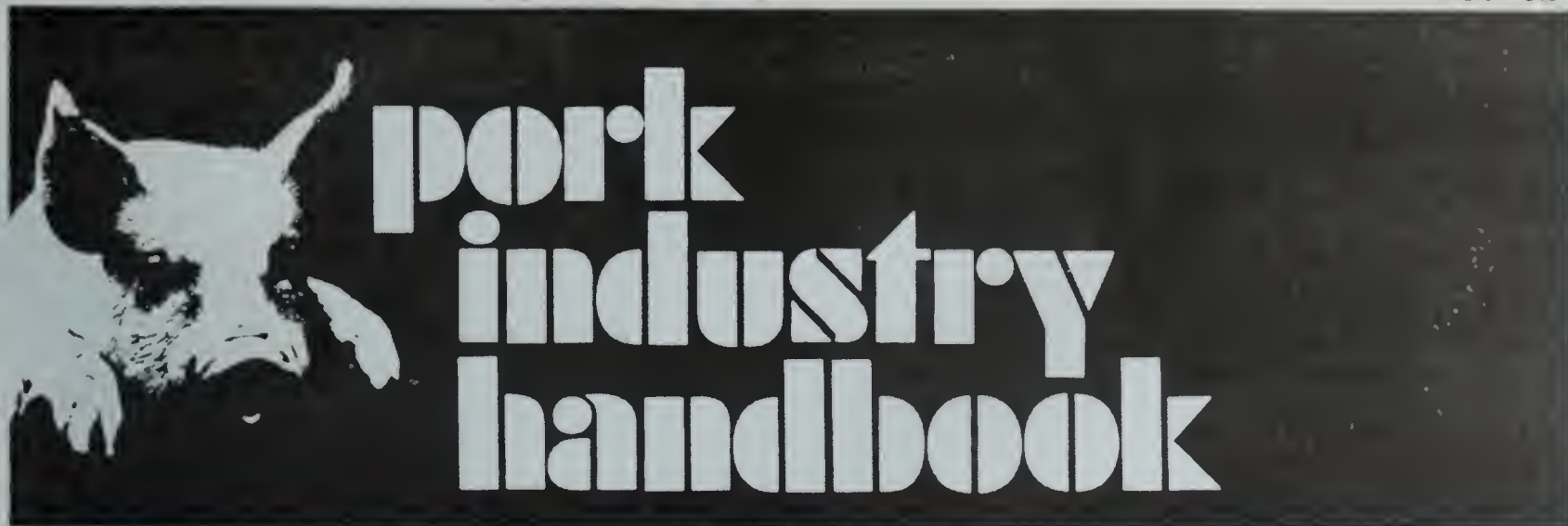
When chronic pneumonias are associated with atrophic rhinitis, treatment levels of broad spectrum antibiotics should be added to the ration for 10 days or longer.

Vaccines

Vaccination is a new and useful aid in the control of *B. bronchiseptica* infection. A federally licensed and approved vaccine is now available. The approved procedure for the use of this vaccine is the administration of a dose to the pig at 7 days of age. A second dose is given at 28 days of age. Sows should be vaccinated 4-5 weeks and again 2-3 weeks before farrowing.

Vaccination is a valuable aid in atrophic rhinitis control, but it should be supplemented with the other control procedures previously mentioned.

The local practicing veterinarian is the best resource person in the community to determine which control methods will be the most effective for a particular swine production unit. A veterinarian should also monitor the progress of an atrophic rhinitis control program.



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Swine Dysentery (Bloody Scours, Vibrionic Dysentery, Black Scours)

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Swine dysentery occurs most frequently in 8-14-week-old pigs, although all ages may be affected with the disease. Typically, the pigs pass loose stools containing blood and mucus. When swine dysentery occurs in young weaned pigs, 90-100% of these pigs are affected, and 20-30% may die if an effective treatment is not administered. The disease may also appear in suckling pigs or adult swine. In such cases, the disease is usually mild and may not be readily diagnosed.

Due to unapparent infections of the disease, the economic significance is difficult to assess. In typical outbreaks, losses result from poor rate of gain and feed efficiency, medication costs and death. The Livestock Conservation Institute estimates that swine dysentery causes an annual loss of \$64 million to the U.S. swine industry.

Cause

An anaerobic (growing only in the absence of oxygen) bacterium, *Treponema hyodysenteriae*, has been found to cause swine dysentery. Pathogenic (disease-producing) types of *T. hyodysenteriae* act synergistically with other anaerobic bacteria, which are normally present in the intestinal tract of pigs, to produce the disease. The interaction of pathogenic *T. hyodysenteriae* and the other anaerobic bacteria such as *Bacteroides vulgatus* causes excretion of fluid, electrolytes and excess mucus from the large intestine. As the disease progresses, blood may be lost through the damaged intestinal wall. Death usually results because of dehydration and a loss of electrolytes.

Most herds of pigs harbor a nonpathogenic type of *T. hyodysenteriae*. Although this type is very similar to the pathogenic type, nonpathogenic *T. hyodysenteriae* does not cause disease in pigs. The two types of *T. hyodysenteriae* can be identified by laboratory tests and oral inoculation into experimental pigs. A definitive diagnosis of swine dysentery should only be based on the isolation and identification of pathogenic *T. hyodysenteriae*.

Transmission

Pathogenic *T. hyodysenteriae* is present in the feces of pigs which either are affected with or have recovered from swine dysentery. After susceptible pigs ingest the organism, symptoms of swine dysentery usually occur in 2-21 days; however, longer incubation times have been reported. The incubation period is usually shortened by the ingestion of higher numbers of pathogenic *T. hyodysenteriae*.

It has been shown that sows may harbor pathogenic *T. hyodysenteriae* without having clinical evidence of swine dysentery. The organism is shed in the feces of the sow and transmitted to the suckling pigs. Often, it appears that most pigs are not susceptible to the disease while nursing the sow but subsequently are affected after weaning.

Although *T. hyodysenteriae* is an anaerobe, it will survive in feces for over 1 month. Exact survival time is not predictable because of the influences of variable environment factors such as temperature and moisture. The organism has been found in lagoon water collected from an infected premise. Pigs that have recovered from swine dysentery may shed pathogenic *T. hyodysenteriae* in their feces for over 2 months.

Infectious organisms can be transmitted from farm to farm in feces carried on contaminated boots or vehicle tires. There is also some evidence that other animals such as dogs, birds and flies may carry *T. hyodysenteriae* for periods adequate to permit movement from one premise to another.

Diagnosis

Typical outbreaks of swine dysentery may be diagnosed by observation of several pigs with watery feces containing blood and mucus and by the presence of appropriate lesions at necropsy. If possible, samples should be submitted to a laboratory for isolation and identification of pathogenic *T. hyodysenteriae* to make a definitive diagnosis of swine dysentery.

Several other diseases commonly confused with swine dysentery are: salmonellosis, trichuriasis (whipworm

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Table 1. Dosage level, duration of administration, and withdrawal time for various drugs used for the treatment and/or prevention of swine dysentery.*

Compound	Treatment		Preventive Level	Withdrawal time (days)
	Level	Duration (days)		
Bacitracin	100 g/ton feed	6	50-100 g/ton feed	None
Carbadox	50 g/ton feed	continuously	50 g/ton feed	70
Chlortetracycline	100-200 g/ton feed	3-5	50-100 g/ton feed	None
Dimetridazole†	0.025% in water	5	100 g/ton feed	ND‡
Furazolidone	300 g/ton feed	10-14	100 g/ton feed	5
Gentamicin†	50 mg/gal	3-5	ND	ND
Iprnidazole†	0.005% in water	7	100 g/ton feed	ND
Lincomycin	100 g/ton feed	21	40 g/ton feed	6
Neomycin	140 g/ton feed	3-5	100 g/ton feed	20
Oxytetracycline	100 g/ton feed	3-5	50 g/ton feed	None
Ronidazole†	0.006% in water	5	ND	ND
Sodium arsanilate	4.5 grains/gal water	5-7		5
	225-360 g/ton feed	5-6	90 g/ton feed	5
Tylosin	0.25 g/gal water	5-6	100 g/ton feed	None
	200 mg/da (injectable)	3		4
Virginiamycin	100 g/ton feed	14	25 g/ton feed	None

* From *Diseases of Swine*, ed H.W. Dunne & A.D. Leman, 4th ed. Ames, Iowa; Iowa State University Press, 1975. Chapter 28 "Swine Dysentery," by D.L. Harris & R.D. Glock.

† These compounds were not approved for administration to swine in the United States at the time this table was compiled.

‡ Not determined.

infestation), necroproliferative enteritis (hemorrhagic bowel syndrome) and gastric ulcers. An accurate diagnosis of gastrointestinal disorders must be based on a thorough examination of the entire pig at necropsy and submission of samples for microscopic and cultural evaluation.

Treatment

Pigs that are gaunt and depressed due to swine dysentery should be treated with drugs in the water. Usually affected pigs in the early stages of disease consume very low amounts of feed. Therefore, treatment via the feed alone is not always effective. Pigs with swine dysentery may also be treated by injection of drugs, but, this is usually impractical unless very few animals are affected.

If possible, during treatment, the pigs should be dispersed into a larger area, and the floor of the pens should be cleaned daily to decrease re-exposure to pathogenic *T. hyodysenteriae*. The severity of outbreaks appears to be less if electrolytes are administered via the water and the feed is changed to a low-energy, high-fiber content.

Table 1 lists the various drugs which are being used for the treatment of swine dysentery. As with other infectious diseases, drugs that have been available for a number of years are often less effective. Carbadox, Virginiamycin, and Lincomycin are the drugs which have been approved most recently by the Food and Drug Administration.

Prevention

No vaccine has been developed for the prevention of swine dysentery. Since the disease is so economically devastating, great care should be taken to prevent introduction into a noninfected herd. Pathogenic *T. hyodysenteriae* can be carried into a herd on boots, farm implements and trucks. Isolation of the herd and rodent and dog control are essential to reduce this potential hazard.

Introduction of new stock is an even greater hazard. At present, a reliable history of the source herd is the only assurance of safety. Research is being conducted to develop cultural and/or serological procedures to detect herds infected with pathogenic *T. hyodysenteriae*. Unfortunately, no methods are available to screen individual herd additions for the disease. Quarantine of all new animals is an excellent procedure, especially since clinical signs often appear in subclinically affected animals as a result of stress due to transportation.

Losses in affected herds can also be reduced or prevented by various management procedures. Outbreaks of swine dysentery are often associated with conditions that produce stress such as handling, transportation, severe weather or dietary changes. Minimizing stress or using preventive levels of various approved compounds

may be useful aids. Sanitation is also extremely important since the severity of the disease within an individual or a herd is directly related to the quantities of contaminated feces that are ingested. Reducing crowded conditions and providing a clean, dry environment can produce dramatic results. Conversely, poor sanitation will greatly enhance the distribution and severity of the disease within a herd. An example of this may be seen occasionally in herds in northern latitudes where severe outbreaks have followed overfilling of waste pits under slatted floor systems where outlets became frozen.

Depopulation is a rather drastic, but frequently necessary, measure taken to eliminate chronic swine dysentery. Because the causative agent is anaerobic and susceptible to heat, oxygen and drying, it is recommended that depopulation be done during warm, dry weather, if possible. Thorough cleaning and disinfection should be followed by fumigation of enclosed buildings. The time often recommended as a suitable waiting period before introducing new stock on dirt lots is 90 days. The lots involved should be plowed prior to introduction of new animals. Swine waste lagoons and pits also present potential hazards because swine dysentery can apparently persist for at least a few days in these systems. The period required for waste lagoons and pits to become completely safe is not known.

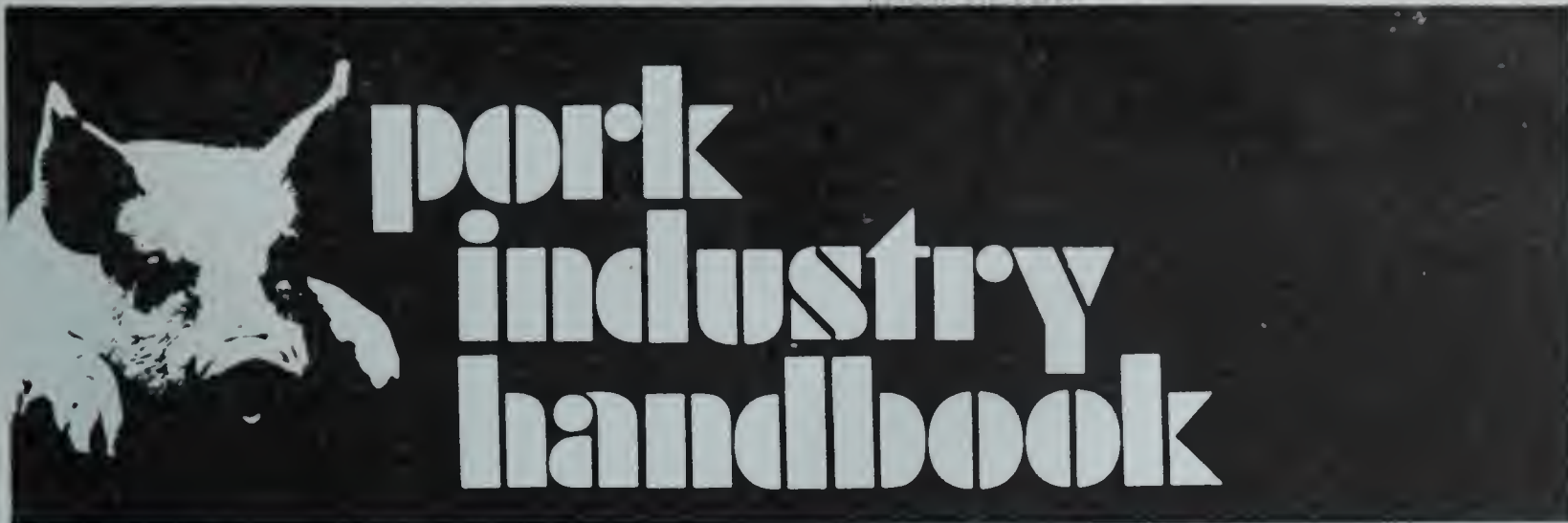
Repopulation is extremely critical because any preventive procedures are useless if carrier pigs are introduced into the herd. Only primary SPF stock or animals from reliable sources should be considered as replacement stock.

Serious losses may be prevented even in exposed herds by the use of preventive levels of various therapeutic compounds (Table 1). The judicious use of these compounds as described in the section on therapy may be very beneficial, but these compounds should not be relied upon as a substitute for good management.

Elimination of the Disease from a Herd

Experimentally, pathogenic *T. hyodysenteriae* may be eliminated from pigs by certain medications. To accomplish this, survival of pathogenic *T. hyodysenteriae* in the environment must be prevented. During treatment, pens should be cleaned and disinfected daily. After treatment, the pigs are then moved to thoroughly disinfected premises. It is possible that this method could be utilized to eliminate the disease from a herd, but no documented attempts have been reported.

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Transmissible Gastroenteritis (TGE)

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Among the diarrheal diseases of baby pigs, transmissible gastroenteritis (TGE) is the most deadly and the most feared by swine men. Accurate statistics are not available, but extensive epidemics of TGE occur every winter in the Swine Belt. When the disease strikes a herd during a concentrated farrowing period it is not unusual to lose most of the pigs farrowed over the next two to three weeks.

Clinical Signs—Appearance

TGE is usually a mild disease except in pigs less than about 3 weeks of age and in sows that sicken at or near farrowing. Pigs other than these have a more or less fluid diarrhea for 1 to a few days, and vomiting is occasionally observed. They may not gain, or may actually lose, weight for a week or so, but in most cases they make up these losses later.

The signs in newborn pigs are much more severe. Diarrhea starts 18-30 hours after the pig is exposed to virus. Thus, pigs born in a farrowing house in which a TGE outbreak is going on are born healthy and show the first signs of TGE on the day following birth. Diarrhea that sometimes occurs in pigs during the first hours of life is not TGE.

The first sign seen in baby pigs that are carefully watched is almost always vomiting. This may be missed in pigs housed in pens in which the sows run loose, because they will eat the vomitus. Vomiting is followed very quickly by diarrhea. The first diarrhea, again, can be missed by a casual observer because it is very thin and watery; it runs down the hind legs and drips from the tail. As the disease progresses, it becomes more obvious. The diarrhea thickens, becomes yellowish and is seen in little puddles on the floor.

The pigs are dehydrated, their ears lie back, their eyes are sunken, they are thirsty and will drink water or attempt to suckle even though they become progressively weaker.

Most pigs that die of TGE do so in 3-5 days after they are infected, but in some herds deaths may occur earlier. Pigs that have TGE are highly sensitive to chilling, and this may be at least a partial explanation for the rapid deaths sometimes seen. Pigs that live more than 5-6 days will usually recover. In most cases these pigs will do well, but in some herds there may be pigs that never make satisfactory gains thereafter.

Sows that sicken just before or just after farrowing become feverish, they often vomit, refuse feed and have a greenish diarrhea that persists for 1 to a few days. Their milk quantity diminishes and they may even dry up, but in most cases if the litter continues to suckle they will return to normal lactation.

The Cause

TGE is caused by a virus that belongs to the group called coronaviruses. They have projections on their surfaces that appear in electron micrographs like sunflower petals. The virus has an envelope that is easily destroyed by detergents, and it is readily inactivated by warm temperatures, drying, and sunlight. The virus is resistant to acid—this allows it to pass through the stomach and infect the small intestine. It survives for long periods in a cold, dark environment and almost indefinitely when frozen.

How the Virus Causes Disease

TGE virus has a special affinity for the cells that line the small intestine. These cells cover millions of tiny villi that project into the intestine to provide a huge surface that functions to digest and absorb nutrients from ingested food (Fig. 1). When TGE virus enters these cells it multiplies and, in the process, kills the cell. This process takes 4-5 hours. When the cell is killed, thousands of virus particles are released to infect other cells on other villi. After 4-5 cycles of virus multiplication almost all of the digestive cells in a

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Figure 1. Scanning electron micrograph of normal small intestine, showing villi that line the intestine. These projections increase the surface area and are covered with the cells that digest and absorb nutrients from the feed. x200. Courtesy of Dr. G. L. Waxler, Department of Pathology, School of Veterinary Medicine, Michigan State University.



newborn pig are killed. The small intestine is now covered with immature cells that cannot function in digestion or absorption (Fig. 2).

Food (milk) is taken in, but the nutrients in it cannot be digested nor absorbed so it passes through the pig as diarrhea, taking body water and essential salts with it. The diarrhea upsets the balance of salts in the blood so that it becomes acid. The loss of water causes dehydration, and failure to absorb energy causes starvation. The pig dies of a combination of these factors, with complications of stress and secondary infections often involved.

Diagnosis

An accurate diagnosis is necessary to establish treatment and management of the infected herd. A strong presumptive diagnosis of TGE may be made on the basis of the clinical picture in many outbreaks of TGE. The pattern of a rapidly spreading diarrheal disease involving breeding stock and growing pigs as well as piglets is very typical of TGE but is not always seen. It may be different, for instance, where no baby pigs are present or when part of a herd is immune. Postmortem finding of severe shortening of the villi of the small intestine as shown in Figure 2 is indicative of TGE, but some degree of villous atrophy may occur in other diarrheal disease of pigs, notable rotaviral infection, so these lesions require interpretation.

Many diagnostic laboratories are equipped to do a fluorescent antibody test which can detect TGE virus-infected cells in the intestines. This test is specific and can be done in less than a day; but it requires the killing of 1 or more pigs, preferably at the earliest stage of infection, to obtain intestinal tissue. A diagnosis can be made by using serological tests on blood samples taken at the time of disease and 2 or 3 weeks later. Usually such a retrospective diagnosis is made too late to influence treatment or management of the affected swine, but it may influence the long-term management of the herd.

In some herds, an atypical pattern of TGE occurs in pigs whose mothers are immune owing to a previous exposure to the disease. In such herds, diarrhea occurs mainly in suckling pigs over 8 days of age or in recently weaned pigs.

This form of TGE, commonly referred to as enzootic TGE, occurs mainly in herds that are on a frequent or continuous farrowing schedule, presenting a situation where susceptible pigs are generally present to perpetuate the infection. An accurate diagnosis of enzootic TGE can be difficult, and it must be differentiated from diarrhea due to rotavirus since the latter also occurs mainly in pigs of this age group.

Immunity

One of the most effective and widely used methods of combating viral diseases is immunization, but in spite of considerable effort by universities and commercial houses, a completely safe and effective TGE vaccine is not available at this writing. Immunity to TGE and other diseases of the intestine is a complicated subject and still incompletely understood.

The problems with immunity to TGE stated briefly and with oversimplification are: To be effective against TGE, pigs must have immunity during the first days of life. A sow that has been infected naturally will give immunity to its pigs through its colostrum and milk. Its pigs will be immune, however, only as long as they suckle the immune sows. If they stop suckling they become susceptible within hours because their immunity depends upon the presence of milk antibody in the gut.

A TGE vaccine is available commercially and can be used to vaccinate pregnant sows to provide some temporary protection to their suckling pigs. This type of vaccine, as presently available, provides only limited protection against infection but will tend to reduce death losses in young pigs. The practical problem that has not been solved is to develop a safe vaccine that will stimulate the same antibodies in sow's milk as natural infection does. Injected vaccines cause antibody to appear in colostrum (the first milk), but 1-3 days after farrowing, and thereafter, only low levels of antibody occur in milk. Thus, the pigs of a sow given an injected vaccine may be protected very early in life while suckling colostrum but not later as the colostrum is replaced by milk.



Figure 2. Scanning electron micrograph of the small intestine, as it appears after infection with TGE virus. The surface cells are killed and shed resulting in shortening of the villi and loss of the ability to digest and absorb nutrients. If the pig survives, villi will regain their original form in 1 week to 10 days. Courtesy of Dr. G. L. Waxler, Department of Pathology, School of Veterinary Medicine, Michigan State University.

It is possible to produce substantial immunity by planned infection of sows with fully virulent TGE virus. This is dangerous because a planned infection may not be contained; it may be spread to other swine in the same herd or to other herds in the area and, actually, start an epidemic. Planned infection with virus obtained in the form of intestines of infected pigs can, however, be an important management tool when it is used judiciously in herds that are already infected.

A theoretically possible approach to immunization would be to give newborn piglets a modified virus by mouth. This would require a virus that is able to stimulate interference with the growth of wild TGE virus without causing disease on its own. So far, this has not been attained.

Epidemiology

The most cost-effective means of controlling disease of livestock are based on sanitation; that is, keeping the animals and causation separated. Good sanitation procedures depend upon knowledge of the epidemiology of the disease in question. There are still many unanswered questions as to how TGE virus survives and spreads in nature because such research requires keeping swine for long periods in isolation. It is time-consuming and expensive, and relatively little has been done. Thus, what is stated here as fact may have to be revised as new knowledge is developed.

TGE is a disease primarily and, as far as is known, exclusively of swine. No reservoir of infection other than swine has been identified. Dogs and foxes can become infected with TGE virus, and they may shed the virus in their stools for up to 2 weeks. They could be involved in herd-to-herd spread of virus during an epidemic but not likely in the survival of the virus from year to year. Starlings tend to flock into feedlots during the winter when TGE is most prevalent, and circumstantial evidence suggests that they may be involved in herd-to-herd spread of TGE virus during epidemics. Attempts to infect starlings with TGE virus have failed, but virus can survive in their intestines for some hours. Thus starlings could eat feed contaminated with virus at one farm and shed the virus in their stools a few

hours later at another farm. It is also possible that starlings carry virus from herd to herd on their feet or feathers. There is nothing, however, to indicate that they function to keep TGE virus alive from one season to another.

The most important animals involved in the maintenance and spread of TGE are swine and man. Swine are the reservoir of the virus, and man, through his activities, helps spread the virus from herd to herd.

The natural route of infection of pigs with TGE virus is by mouth or, in close quarters, virus may be airborne and pigs may be infected by inhaled virus. Virus multiplies in the gut and is passed out in the stools in which it is available to infect other pigs. The quantity of virus in the diarrhetic stools is very high (up to a million infectious doses per gram) during the first days of the disease. It decreases as the pigs recover and the stool becomes solid. With one questionable exception, virus has not been found in the feces of pigs for more than 2 weeks after infection. Virus may persist in the gut and possibly the respiratory tract for as long as 2 or 3 months. Whether this virus ever gets out of such pigs to start new infections is a matter of question.

It is known that TGE virus can persist for long periods under conditions in which new pigs are continuously added to a group. In large herds in which continuous farrowing is practiced, for instance, most of the sows may be immune and their pigs will be totally or partially protected while they are suckling the sows but will have no protection after weaning. As discussed under "Diagnosis," this pattern of enzootic TGE in a herd can be difficult to diagnose.

The disease in weaned pigs is not generally fatal, nor distinguishable clinically from other diarrheas that occur after weaning; but such a herd may provide a reservoir of TGE virus which may escape and infect other herds when conditions are favorable to its spread. It seems logical that other situations in which pigs are continuously assembled, such as feeder pig concentration points, may also serve to maintain TGE virus, but this has not been documented.

The important means of spread of TGE virus between herds is stool (feces) from recently infected pigs. It can be carried between herds most effectively by movement of pigs but, also, by anything that is likely to be contaminated

with manure and move between herds. This includes equipment, feed, trucks, and people. People may carry virus on their hands and clothing as well as on their shoes or boots.

Almost all new TGE outbreaks occur in the winter. This can be explained at least partially by the fact that the climatic conditions of winter, that is, low solar radiation due to long nights and cloudiness, and low temperatures, favor the survival of the virus as it is carried between herds in pig stools. The conditions of intense solar radiation and high temperatures that occur in the summer almost eliminate the chance for virus to be carried between herds. Also of possible importance is the tendency for large numbers of starlings to feed close to swine in the winter months, especially after a snowfall.

Treatment

As is the case with almost all viral diseases, no drugs are effective against TGE virus in swine. Lacking specific antiviral drugs, treatment must be directed at the effects of the virus rather than at the virus itself. As was indicated above, the cause of death in TGE is starvation, dehydration and acidosis. It would be possible, theoretically, to replace all of the water, nutrients and electrolytes that are lost through diarrhea by injecting them intravenously or subcutaneously. To some extent this has been done in the laboratory, but the process is expensive and time-consuming and is still not practical on the farm. It is possible, however, to alleviate or at least reduce dehydration by supplying drinking water and to decrease the demand for energy by keeping pigs warm.

Doing two things for TGE-infected pigs—keeping fresh water before them at all times and providing a draft-free place with a temperature of 90+ F.—can significantly reduce losses especially in pigs that are 3-4 days or more of age at the time they are infected. Pigs that are infected during the first day of life do not cope as well.

In some cases secondary bacterial infection appears to be involved importantly, and antibiotic treatment may be advisable even though it will not affect the course of the viral infection in the pig.

Management of TGE-Infected Herds

Management is the most effective and least expensive means of reducing losses in a TGE-infected herd. It should be directed not only at saving pigs already infected, but also at preventing infection of pigs to be farrowed and, very importantly, preventing spread to other herds in the area.

It is, however, very difficult to make blanket recommendations since each herd is different in facilities, farrowing schedule, marketing aims, availability of labor and many other factors that influence management discussions. This is where a veterinarian who understands in detail the pathogenesis, epidemiology, and immunity to TGE (which were briefly outlined above) can be most useful. Some procedures to be considered follow:

Pigs born to non-immune sows in a room in which other pigs have TGE are almost sure to break out with TGE on the

second day of life. Therefore, sows to farrow in the 10 days or 2 weeks after an outbreak starts should be moved to other quarters. In addition to reducing the probability that their pigs will become infected, this shortens the time that the farrowing room will be contaminated. Individual houses with attached pens, separated from each other by a few feet, are ideal but not usually available on modern farms. It is usually possible, however, to find some accommodation for sows outside of the infected farrowing house even though it otherwise would be considered inadequate. It is often surprising how effective this procedure can be. Even sows that farrow as early as the first night after removal from the contaminated farrowing house may have litters that remain healthy if care is taken to maintain their isolation.

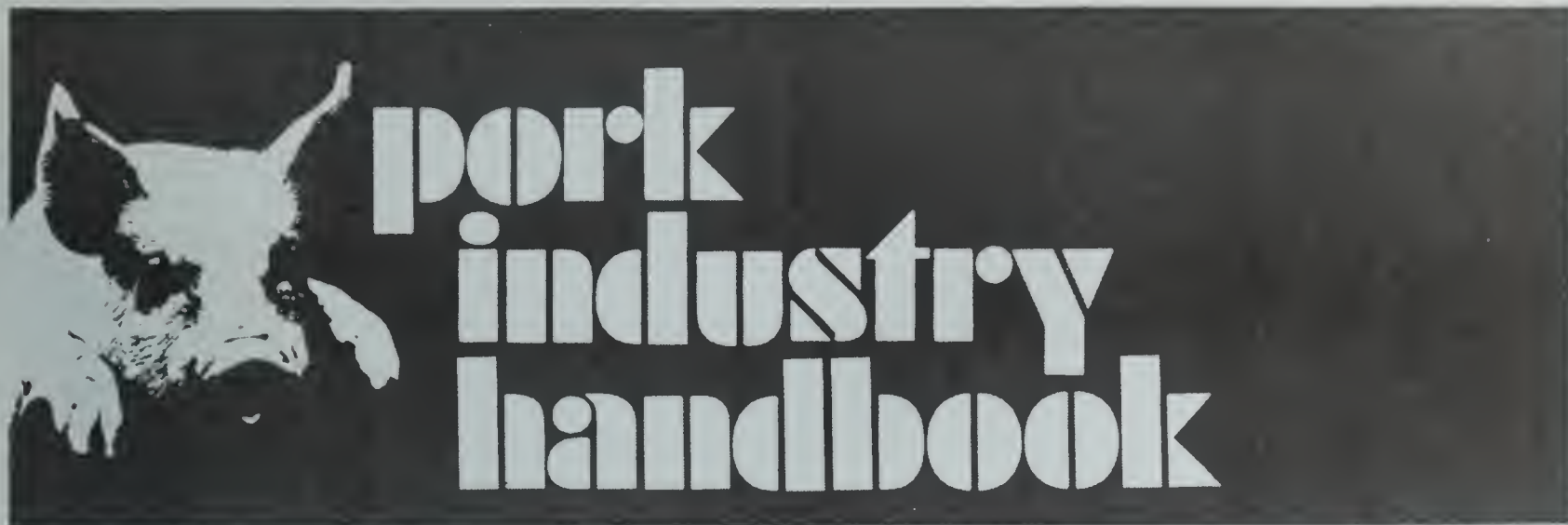
Deliberate infection of sows with the virus already on the farm may be useful. This is best done by chopping or grinding the virus-containing intestines of newly infected pigs in water, and adding the slurry to the sows' feed. The infected sows develop some immunity in about 10 days and it becomes stronger during the next weeks. Such sows may then be moved into the farrowing house. The effectiveness of this procedure is increased if, in the meanwhile, all sick pigs are removed and the room is thoroughly cleaned and allowed to stand at about 70-80 F. for 2 or more days.

Under some circumstances, it may be useful to deliberately expose growing swine as well as sows. The reason for this is that it may shorten the total time the disease is active on the farm over what it would be if the infection were to progress naturally through the herd.

Decisions concerning planned infections should be made with professional consultation to assure proper handling of the virus and infected animals. It is possible to spread agents other than TGE virus in this way, and improper management could result in swine being infected at the wrong time, or the infection may be spread to swine other than those intended.

Preventing spread of TGE to other farms is an important responsibility. Dead pigs should be incinerated or at least kept in a container so they are not available to dogs or vermin that may travel between farms. Workers should not go to other farms or to places where other pork producers gather without a complete change of clothing.

A perennial question raised by pork producers is how long one should wait before infected or exposed swine can be safely moved into other herds. A common recommendation is that swine should not be moved between herds for at least 1 month after the last signs are seen in the herd. This period is somewhat arbitrary since it has been shown that virus may actually persist in pigs for longer periods, but no cases of spread from swine sold after such a time have come to our attention. The actual time should be based upon such factors as the need for the sale, the possible consequences of transmitting infection, the possibility of quarantine of the pigs in the herd receiving them, the time of year and an understanding with the new owner.



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Enteric Colibacillosis of Newborn Pigs

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Names such as *E. coli* diarrhea or scours, baby pig scours, and colibacillosis are popularly used today to label an intestinal disorder of newborn swine characterized by large amounts of liquid feces. Research has shown that some strains of *Escherichia coli* bacteria can cause such intestinal disorders, but there are also other bacteria and viruses which can cause diseases with some more or less similar clinical signs. Within any herd, these different infectious agents may cause disorders concurrently or sequentially. This summary was prepared specifically to help the readers understand some of the current knowledge about *E. coli* infections.

It is often necessary to conduct laboratory tests to establish an accurate diagnosis. Properly collected specimens from carefully selected pigs are required for meaningful diagnostic efforts. Even then it may be difficult to establish the diagnosis for a particular episode of diarrhea. Too frequently, costly chemotherapeutic agents are administered on the assumption that the diarrhea is being caused by *E. coli* when, in fact, the disease is being caused by a virus (such as TGE or rotavirus) or another microorganism that is completely unaffected by the drugs used.

Cause

E. coli are normal inhabitants of the intestinal tract and are present in large numbers in the large intestine but not the small intestine of normal animals. However, certain strains are classed as enteropathogenic, meaning that they produce disease by developing in the intestine without necessarily invading the other tissues of the body. Enteropathogenic *E. coli* are found throughout the world; there is probably at least one strain in each herd. It is important to understand that the incidence of disease caused by enteropathogenic *E. coli* is greatly influenced by the management of herd and

facilities. Such strains of *E. coli* have the ability to propagate rapidly in the small intestine. Additionally, these strains produce toxins (enterotoxins) which cause massive fluid losses from the body. The amount of fluid and electrolytes in the small intestine soon exceeds the absorptive capacity of the intestine. Consequently, large quantities of pale yellow, watery feces are passed. The fluids are lost at such a rapid rate that the pig becomes dehydrated and also develops acidosis because a large proportion of the electrolytes lost are basic. The liquid feces are usually quite alkaline. The pigs usually are thirsty and continue to nurse until they become too weak and depressed to do so.

This fact sheet is directed primarily to neonatal enteric colibacillosis, which is diarrhea caused by enteropathogenic *E. coli* in pigs less than 7 days old. A number of host and environmental factors affect the incidence of *E. coli*-caused diarrhea of newborn pigs. The stomach and intestine of pigs are quickly flooded with bacteria immediately after birth. Many of these are "harmless," but if large numbers of enteropathogenic *E. coli* are present, many pigs will probably be infected immediately after birth.

Large numbers of *E. coli* are usually present in the immediate environment whenever it is dirty and wet, the ventilation is poor, and the humidity is high. However, the most important source of infection is other young pigs with *E. coli* diarrhea. These pigs will shed up to 1 billion *E. coli*/cc. of the liquid feces.

Temperature is probably the most important of all the environmental influences on the well-being of the pigs. It is also one of the easiest to control in modern farrowing facilities. Young pigs are extremely sensitive to chilling, and this stressor lowers the resistance of pigs to infections including *E. coli*.

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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Charles E. Barnhart, Director of Cooperative Extension Service, University of Kentucky College of Agriculture, Lexington, and Kentucky State University, Frankfort.

Newborn pigs normally have no antibodies at birth but receive them from the colostrum (first milk) of the sows. Colostrum has antibodies against many different microorganisms depending upon what the sow has been exposed to or vaccinated with. Frequently, gilts have had less exposure to the enteropathogenic *E. coli* in the herd and consequently don't protect their pigs as well as sows. If the pigs drink colostrum (containing adequate levels of antibodies against the infecting strain) immediately after birth, and if they continue to suckle regularly, the *E. coli* will usually be inhibited sufficiently to prevent the occurrence of clinical disease. However, all protection is relative, and infection with very large numbers of enteropathogenic *E. coli* or anything that interferes with frequent suckling (such as lactation failure, injuries or other infections) increases the probability of development of clinical colibacillosis.

Pigs that develop *E. coli*-caused diarrhea must be treated very promptly with antibacterial drugs which have been shown to be effective against the enteropathogenic *E. coli* in the herd. The disease is so acute in young pigs that even with proper treatment, death and performance losses make this a very costly disease. It is much more profitable to prevent this disease than to be continuously treating affected pigs.

With this introduction, it should be obvious that the best possible results in the prevention of *E. coli*-caused diarrhea of baby pigs can be attained only by a complete program using all the good management practices available.

Prevention

There are three basic approaches to the prevention of *E. coli* scours. The first approach is a good sanitation program to reduce the number of enteropathogenic *E. coli*. Sanitary farrowing facilities and adequate ventilation are essential to reduce the number of pathogenic organisms and to prevent high humidity and damp or wet floors. Promptly covering the liquid stools with dry bedding or soil can help reduce the spread of bacteria from pigs with *E. coli* diarrhea. In addition, if *E. coli* diarrhea is diagnosed, the affected pigs should be promptly treated with antibacterial drugs known to be effective (either by laboratory tests or experience in that herd) against the particular strains present in the herd. This of course is a treatment for the affected pigs, but it is also an attempt to decrease the number of enteropathogenic *E. coli* that these pigs are shedding in the liquid feces. It is important that the antibacterial drugs not be used indiscriminately because *E. coli* often rapidly develop resistance to these drugs.

The second approach is to use good management practices to maintain the "natural" resistance of the newborn pig at the highest possible level. Attention to the nutritional and general health status of the breeding herd helps insure the delivery of vigorous pigs and satisfactory lactation. Prompt suckling after birth, and frequent suckling thereafter, is necessary for the pigs to acquire the full benefits of the specific and non-specific protective substances in the sow's colostrum and milk. Colostral antibodies must be swallowed every few hours to keep enough in the intestine to protect the pigs. As previously mentioned, chilling caused by drafts, and wet or cold floors or inadequate heaters must be avoided because chilling is one of the most severe stressors a young pig can encounter. Pigs should be warm enough to sleep soundly in a stretched-out position. Pigs in wet pens, or pens with inadequate heat, huddle, shiver and are restless, continually moving to find a warmer spot in the pile.

The third approach to the prevention of *E. coli* scours of baby pigs is to increase their resistance. The pig can

get specific protection against infectious diseases from its dam through the colostrum and milk. This can be enhanced by vaccination of the dam. Vaccination of sows to increase the protective value of their colostrum and milk against enteropathogenic strains of *E. coli* has been attempted by many people.

One vaccination method currently being used successfully in numerous herds by veterinarians, and recommended by us, involves feeding cultures of *E. coli* to dams late in gestation. The vaccinated dams then protect their newborn pigs via antibodies in their colostrum and milk. The program must be custom-developed for each herd, partially because there are so many strains of *E. coli* that can cause scours of baby pigs. Antibodies produced against any one of these strains are not very effective against most of the other strains.

There are a number of precautions to follow. Only pure *E. coli* cultures isolated from the herd to be vaccinated should be used. The aim here is to avoid bacteria or viruses that are useless for vaccination, or even worse, feeding bacteria or viruses that could cause disease problems in the herd. This program has a number of rather detailed steps. Good results depend upon a good working relationship between a competent veterinarian and the producer.

Recent research indicates it may be possible some day to formulate effective vaccines to prevent neonatal colibacillosis in many if not all swine herds. Basically, this process involves the production of vaccines with purified virulence factors from enteropathogenic bacteria. Several such factors harvested from different pathogenic strains may need to be incorporated in a universal vaccine.

To achieve optimal benefits from any vaccination program against *E. coli* scours of baby pigs, it will still be necessary to keep the level of pathogenic *E. coli* as low as possible through good management, to insure that pigs suckle promptly and frequently, and to avoid chilling, injuries, and other disease problems.

Colibacillosis in Older Pigs

The intestinal disorders characterized by yellow to white runny or smeary feces frequently observed in suckling pigs 10-35 days of age are often called white or milk scours. In contrast to those of newborn pigs with colibacillosis, these stools are usually neutral or acidic. These stools also have a different appearance from the pale yellow, watery, gassy feces of *E. coli* diarrhea of baby pigs. In many cases this syndrome is also called colibacillosis. Current research indicates that enteropathogenic *E. coli* can be present and occasionally play a significant role in the severity of the disease. However, diagnostic methods being developed indicate that a virus (rotavirus) that is probably present in all swine herds destroys some of the epithelial cells that line the small intestine. (Although the rotavirus can affect newborn pigs, field investigations indicate that it rarely causes clinical disease in pigs less than a week of age if they're nursing healthy sows.) The resulting maldigestion and malabsorption are similar (although less severe) to those in TGE.

The diseases caused by these viruses are discussed in other fact sheets. The role of enteropathogenic *E. coli* in these cases is secondary to the damage caused by the virus. In some cases, *E. coli* may contribute to fluid losses. In other cases, it appears that the *E. coli* become closely associated with the damaged lining of the intestine and may enter the body or release toxins (endotoxins) that are absorbed into the body and cause shock and rather sudden death. Complete diagnostic procedures are indicated, but in the absence of the demonstration of a definite role for *E. coli* in the outbreak it is

difficult to justify the administration of chemotherapeutic agents. In fact, it has been repeatedly observed they are ineffective in controlling "white" or "milk" scours.

Although enteropathogenic *E. coli* undoubtedly can and do contribute to postweaning scours, the precise role and significance is not well defined. As additional research is directed toward postweaning scours, it may well be found that there is a complex interaction of etiologic agents and factors among which *E. coli* may act only in a secondary role here as well.

If a complete diagnosis has been made that definitely incriminates enteropathogenic *E. coli* as having a significant role in an outbreak of diarrhea in pigs over a week of age, the incriminated strains of *E. coli* should be tested to determine which antibacterial drugs are effective against them. The selected drug should be given orally. Good sanitation and ventilation, avoiding overcrowding, and adequate heat are important management practices. At present, further proof is needed before a vaccination program directed at preventing colibacillosis of pigs over 10 days of age can be recommended.

Summary

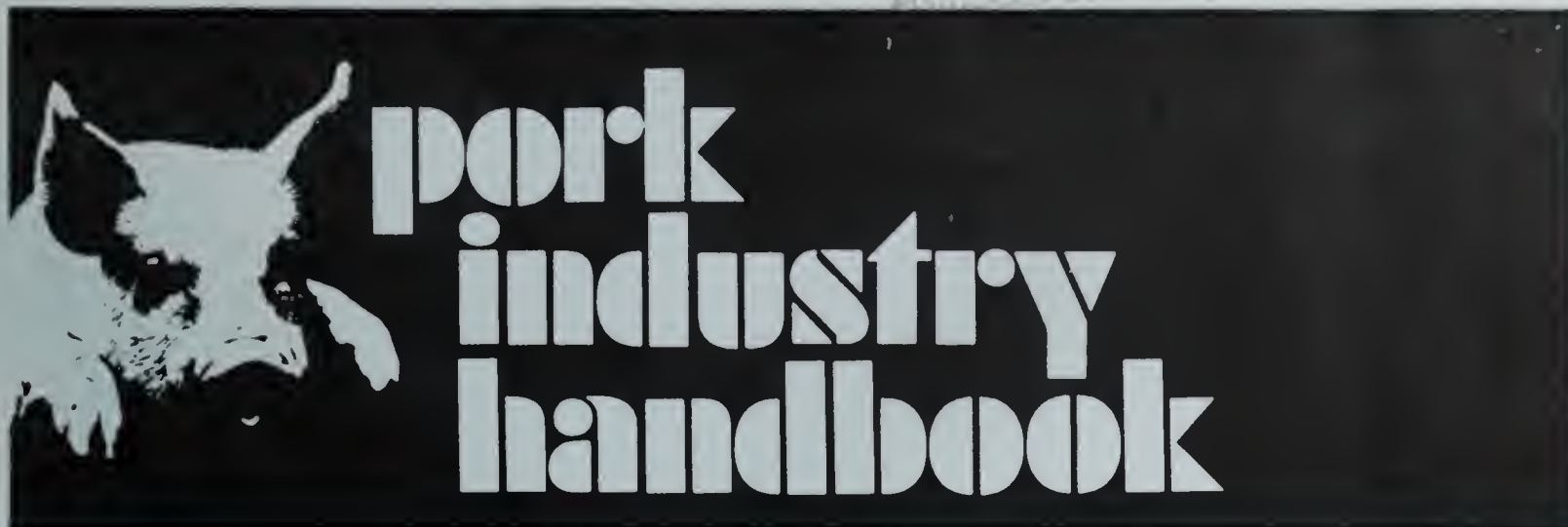
Colibacillosis is a term indeed often used rather loosely and consequently used both correctly and incorrectly. Careful diagnostic study of appropriately collected specimens from carefully selected pigs is required to render an accurate diagnosis. In addition to the detection of substantial numbers of enteropathogenic *E. coli*, the possible role and significance of other enteric pathogens must be evaluated in each outbreak of diarrhea.

Although many drugs are advertised for use in treating *E. coli* diarrhea of newborn pigs, most of these drugs have little effect in many herds since strains of *E. coli*

have developed considerable resistance to them. Laboratory tests with the causative strain of *E. coli* or experience in the herd are necessary to make accurate recommendations about the particular antibacterial drug to use for treatment.

Prevention of *E. coli* diarrhea of newborn pigs is more economical in the long run than treatment of large numbers of cases. There are 3 basic approaches to prevention. The first is a good sanitation program, including adequate ventilation to maintain dry farrowing pens and to keep the number of enteropathogenic *E. coli* as low as possible. The careful design of facilities with only a few farrowing crates per room can be very helpful in making a sanitation program work. The second approach is to establish a good nutritional and health program for the breeding herd to insure the birth of vigorous pigs and a good milk supply. The farrowing house must be operated to avoid stressful conditions for the sows (particularly overheating) and the pigs (particularly chilling). The third approach is to vaccinate the sows so that they can provide better protection for the pigs.

A vaccination program using pathogenic *E. coli* from the herd is frequently indicated where there is a high incidence of *E. coli* scours of newborn pigs. This may occur when a very pathogenic strain of *E. coli* is introduced into the herd or when there are deficiencies in the management and farrowing facilities. The optimal benefits from vaccination can be achieved only when these defects are corrected. Diarrhea in pigs over a week of age should not be assumed to be caused by *E. coli*, but a careful diagnosis should be made. If *E. coli* are demonstrated to be an important cause of the problem, antibacterial drugs that are effective against the causative strains should be given orally.



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Rotaviral Diarrhea in Pigs

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Recently, a group of viruses known as rotaviruses has been found to be a frequent cause of diarrhea in the young of many different animals and man. In 1976, a porcine rotavirus was first reported as a cause of diarrhea in pigs. Since then, only limited information has become available about rotaviral diarrhea in pigs; thus, this report will be incomplete in many respects. However, since infections are very widespread and common in swine, especially infecting young pigs, this fact sheet is included in the Pork Industry Handbook.

The Cause

Rotaviruses have been isolated from different species of animals besides pigs. At least 2 other types, a bovine (calf) rotavirus and a human rotavirus, can also infect and cause diarrhea in pigs; however, there have been no reports of pigs being naturally infected with the bovine or human rotavirus. The name "rota", which is Latin for "wheel," comes from the wheel-like appearance of the virus when seen through an electron microscope. Rotaviruses have been difficult to grow in the laboratory, and this has delayed the recognition of and the research findings on rotaviral diarrhea.

Clinical Signs and Epidemiology

Suckling Pigs. Rotaviral diarrhea has been reported in 1- to 6-week-old suckling pigs, but is probably most common in pigs about 3 weeks of age. It appears that rotavirus is one of the principal causes of a widespread and common type of diarrhea that has been variously referred to as white scours, milk scours or 3-week scours. Some veterinarians and pork producers believe that white scours occurs when pigs ingest more milk than they can digest, which often takes place in litters of high milk-producing sows at about 3 weeks of age. Suckling pigs under 1 week

of age seldom have rotaviral diarrhea, apparently because they have obtained sufficient immunity from nursing their mother. Rotaviral diarrhea has not been reported in pigs over 8 weeks of age.

The diarrhea is characterized by a white or yellow stool which, at the onset, is liquid; but after a few hours or a day, it becomes creamy and then pasty before returning to normal. The duration of diarrhea may be for only a few hours to several days. Vomiting occurs much less frequently than it does in transmissible gastroenteritis (TGE). In most cases, pigs remain active and lose little, if any, weight. Present information suggests that rotaviral infection in many pigs results in either no clinical signs of disease or only a mild disease characterized by a short-term diarrhea. However, field observations indicate that the severity of the disease and the death rate are increased by concurrent infections with pathogenic *Escherichia coli* (colibacillosis) or TGE virus, by inadequate intake of immune milk, and by stress such as chilling. The disease is more severe in younger pigs. Diarrhea is more profuse and, thus, more noticeable in pigs that ingest a large amount of milk.

Outbreaks of rotaviral diarrhea will often be first observed in farrowing or nursery units in 3- to 4-week-old pigs. As the disease spreads, younger pigs are increasingly exposed to the virus and may experience diarrhea at 4 to 10 days of age.

In many respects, rotaviral diarrhea is similar to enzootic TGE (persistence of TGE infection in a herd). Sows are usually not sick in either disease. In enzootic TGE, the usual age for diarrhea is at 1 to 6 weeks of age, depending on management conditions, and the death loss may be from 0 to 20%. The duration of diarrhea is longer, and dehydration and death losses are greater in enzootic TGE than in rotaviral diarrhea.

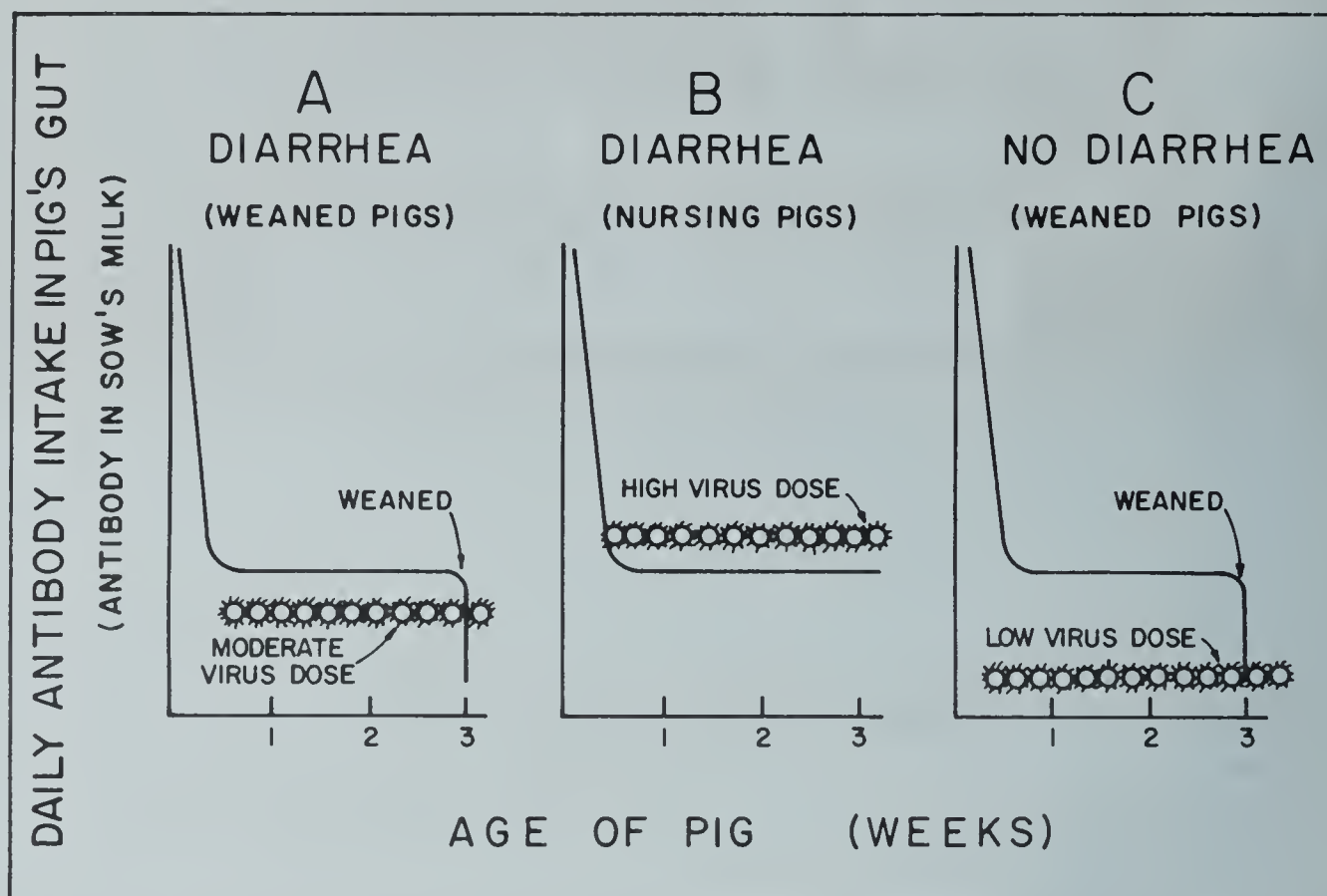


Figure 1. Diarrhea occurs when the dose of virus exceeds the antibody protective capacity in the pig's gut (supplied by sow's milk). A. Diarrhea occurring in pigs weaned abruptly at 3 weeks of age into a moderately-contaminated environment. B. Diarrhea occurring in pigs nursing immune sows in a heavily-contaminated environment. C. No diarrhea in pigs weaned at 3 weeks of age in a lightly-contaminated environment.

Both rotaviral and enzootic TGE are more apt to occur and to be a problem in herds which are (1) on a frequent or continuous farrowing schedule, and (2) which do not practice the "all in and all out" management system in the farrowing or nursery units. As a result, infections may persist in these housing units because each group of incoming pigs becomes exposed and infected by the previous older groups.

Weanling Pigs. Three simple facts must be kept in mind when predicting whether or not rotavirus will be a problem in weanling pigs:

- Rotavirus is widespread in nature. Poor management practices such as continuous use of facilities without benefit of a clean-up, fumigation and a resting time between groups of pigs increases the dose of microbes in the environment, including rotavirus.

- Most sows have protective antibodies in their milk and colostrum (gilts may have less). Rotavirus (like TGE virus) grows in and destroys the cells of the gut. Therefore, to protect the pig's gut cells from rotavirus, antibody must be present in the gut (antibody in the pig's blood is NOT protective).

- The younger the pig, the more vulnerable he is to the diarrhea caused by rotavirus.

Keeping these facts in mind and referring to Figure 1, it is easy to see that pigs will have problems with rotavirus every time the dose of the virus exceeds the protective antibody level in the pig's gut, this antibody being supplied

by the sow's milk. Therefore, the earlier a pig is weaned in a contaminated environment, the more likely a severe outbreak of rotaviral diarrhea will occur. Figure 1A illustrates the situation for pigs weaned at 3 weeks of age. Even though pigs are somewhat resistant to rotaviral diarrhea at this time, the abrupt removal of the pigs from the protective antibody in the sow's milk leaves them vulnerable to the moderate dose of rotavirus that is in their environment. Of course, the earlier the weaning, the higher the death losses. It is also true that if the dose of virus is high enough, pigs nursing immune sows will also experience rotaviral diarrhea in the farrowing house (Fig. 1B). The ideal management situation is illustrated in Figure 1C. In this case, the virus dose is too low to make the pigs sick.

How the Virus Causes Disease

Rotavirus, like TGE virus, has a special affinity for cells which line the small intestines. These cells cover the millions of long finger-like projections—called villi—which make up the inside lining of the small intestines (Fig. 2, A and D). When these cells are infected and destroyed by rotavirus, the villi become short and blunt (Fig. 2, B and E), and nutrients are improperly digested and absorbed. In suckling pigs, much of the ingested milk will pass through the gut without being digested or absorbed and will appear as whole milk or curds. This can result in diarrhea, loss in body weight, and sometimes death.

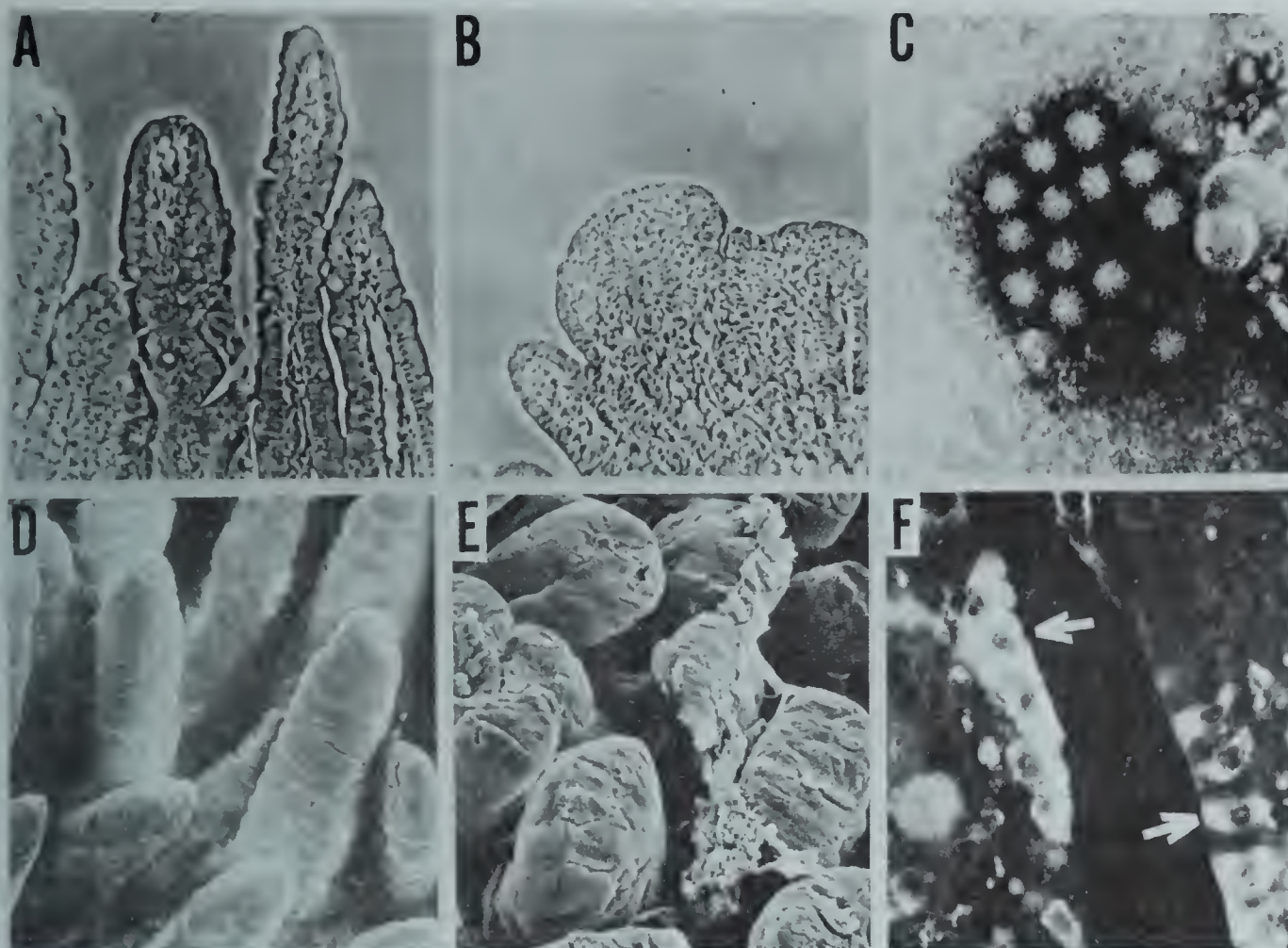


Figure 2. A. Normal villi, (Phase contrast, X75). B. Shortened, blunted villi from an infected pig (Phase contrast, X75). C. A group of rotaviruses (Electron micrograph, X100,000). D. Normal, elongated villi (Scanning electron micrograph, X413). E. Shortened, blunted villi from an infected pig (Scanning electron micrograph, X413). F. Fluorescent antibody stain of a section of the villi of an infected pig; arrows point to rotaviral infected cells, X200.

Diagnosis

Rotavirus should be considered as a possible cause when diarrhea occurs (1) in suckling pigs with a yellow or white stool, especially in pigs over 1 week of age, and (2) in early weaned pigs. Transmissible gastroenteritis virus or pathogenic *E. coli* should also be considered, either occurring alone or in combination with rotavirus. Rotaviral diarrhea can closely resemble enzootic TGE in many respects, and their clinical and epidemiological similarities have been discussed in a preceding section.

For laboratory diagnosis, best results can be obtained if examinations are conducted on specimens collected from live or sacrificed pigs within 24 hours after onset of diarrhea. Laboratory methods which are helpful in making a diagnosis include the following: (1) The lining of the small intestines can be examined for evidence of villous atrophy (Fig. 2, B and E), but this also occurs in TGE. (2) A stool sample or intestinal contents can be examined for the presence of viral particles (Fig. 2C). However, this can be done only by the use of an electron microscope, and few diagnostic laboratories are so equipped for this type of test. (3) The fluorescent antibody test is the one most reliable and applicable for most laboratories at the present time. For this test, scrapings or sections are made from the lining

of the small intestines and are stained by a special procedure. This test will demonstrate those cells which are infected with rotavirus (Fig. 2F). Other laboratory tests are being developed but are not yet proven or are not readily available. Blood testing for the presence of rotaviral antibodies will probably be of little diagnostic help because most swine are positive.

Immunity

Present evidence indicates that most sows have been infected with rotavirus. As a result, they can provide their suckling pigs with a variable degree of immunity. This type of immunity appears similar to that seen in TGE. It has been called lactogenic immunity because it is dependent on the presence of immune milk in the gut, which occurs only if pigs frequently nurse an immune sow. Pigs do not receive an adequate level of lactogenic immunity in three circumstances: (1) when weaned, (2) when milk is ingested infrequently or is of low immune value, or (3) when immune milk in the gut is diluted by ingestion of creep feed. Under these conditions, pigs become more susceptible to intestinal infections. In most herds, sows provide adequate immunity to their suckling pigs for the first week of life, but thereafter,

immunity may be overwhelmed if pigs are severely exposed to rotavirus.

Prevention and Treatment

Most swine herds are probably infected with rotavirus, and there appears to be no practical method for preventing infections in conventional herds. It is even doubtful if the techniques usually employed for maintaining specific pathogen-free herds are adequate for keeping out this widespread and resistant rotavirus, but this remains to be seen. Thus, the problem is how best to live with this infection so as to minimize losses. To answer this need, we require more information on the factors which contribute to the onset of infection and to the severity of the diarrheal disease. It appears that the severity of the disease can be reduced or minimized by providing good sanitation, by keeping pigs comfortable (warm and dry), and by ensuring that pigs get adequate colostrum or milk at an early age.

There is no licensed vaccine for preventing rotaviral diarrhea in pigs. Some veterinarians have orally administered to newborn pigs a commercially-available calf rotavirus (reovirus-like) vaccine for preventing scours in 2- to 4-week-old pigs. However, this vaccine has not been approved for use in pigs and, as such, cannot be recommended. Also, there have not been any reported, controlled experiments indicating benefit of this vaccine. It has been administered to germ-free pigs and colostrum-free newborn pigs by the authors, but no detectable protection was afforded when challenged 19 to 21 days later with porcine rotavirus. However, it is possible that planned infection of suckling pigs at a suitable time or age with a porcine rotavirus could produce only a mild or sub-clinical disease because of the lactogenic type of immunity obtained from the sow, but still be capable of stimulating an adequate level of a durable type of immunity. Undoubtedly, "natural immunization" of this sort spontaneously occurs in those herds which are experiencing little difficulty with this disease.

The prospect of vaccinating pregnant swine with a rotavirus vaccine to provide additional immunity to suckling pigs appears to be of questionable value. The reason is that

most pregnant swine have been infected with rotavirus and as a result may not respond favorably to vaccination or even to additional rotavirus exposure.

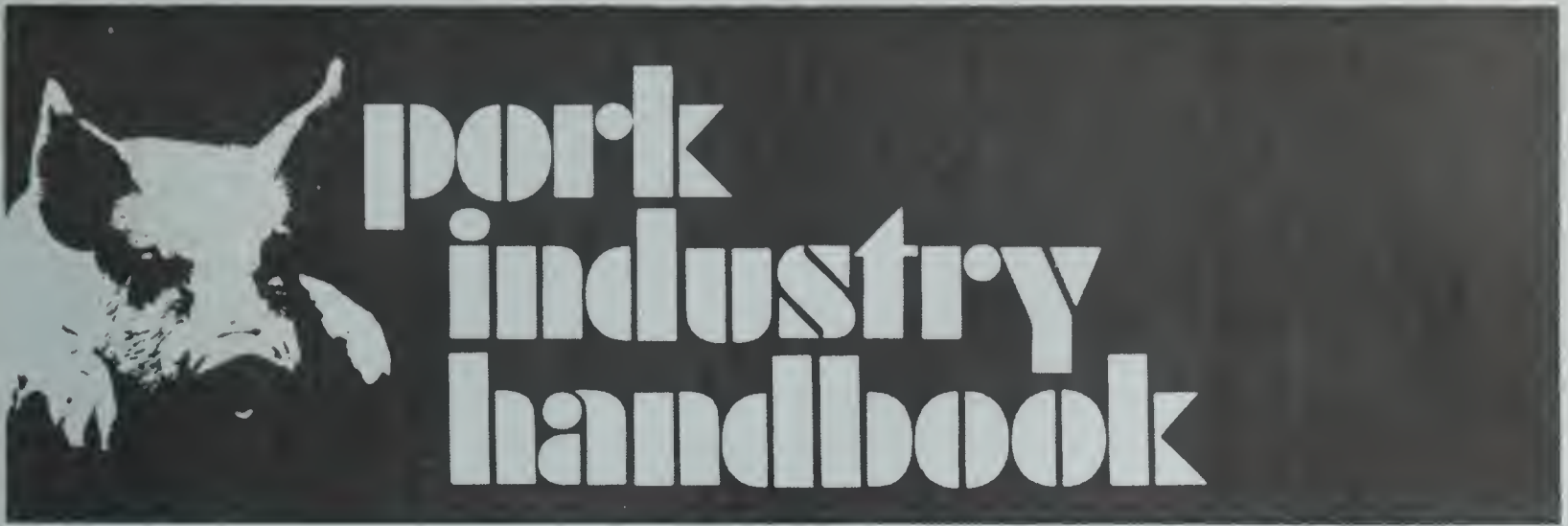
Cow's colostrum contains antibodies to bovine rotavirus. Feeding cow's colostrum has protected lightly-infected piglets, weaned at 1 day of age. In a very preliminary trial, heavily infected piglets weaned at 3 weeks of age were not protected by cow's colostrum.

Antibiotics or other drugs are not effective against rotaviral infections and would be of no value in treatment, unless there is a concurrent bacterial infection, such as with pathogenic *E. coli*.

Summary

Seven points can be summarized from this fact sheet:

- Porcine rotavirus was first reported as a cause of diarrhea in pigs in 1976.
- Infection of swine with this virus is considered very common and widespread. Probably most swine herds are infected.
- This virus is frequently associated with a diarrheal syndrome commonly referred to as white scours, milk scours, or 3-week scours. Diarrhea is most frequently observed in 1- to 4-week-old suckling pigs or in pigs weaned around 3 weeks of age or earlier.
- The infection and diarrhea resemble that seen in enzootic transmissible gastroenteritis but is less serious.
- Laboratory diagnosis can be made by fluorescent antibody staining of mucosal scrapings from the small intestine.
- Death loss in suckling pigs is usually very low unless there are complications owing to concurrent infections or stress, such as chilling.
- Present control measures must rely on good management such as ensuring that pigs get adequate colostrum and milk at an early age, providing good sanitation, and keeping pigs comfortable, especially warm. Protection against pathogenic *E. coli* by immunization or other means should help reduce the severity of rotaviral diarrhea in those herds having combined infections.



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Mastitis, Metritis, Agalactia (MMA)

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Swine agalactia (in the past commonly referred to as MMA or mastitis, metritis, agalactia) is a disease syndrome that results in death of baby pigs through starvation and an increased susceptibility to other fatal diseases of the newborn. This disease is of major importance to the pork producer because of its economic impact. The typical swine agalactia syndrome occurs in the very early stages of lactation. If the herdsman or attendant has been trained to recognize the signs, it may be evident to him at farrowing. Total lack of milk (agalactia) does not occur as frequently as a reduction in normal amounts of milk (hypogalactia). The latter can easily be overlooked; and the assumption that the baby pigs were born weak is often believed as truth when, in reality, the pigs are slowly starving. The number of sows or gilts affected with this disease syndrome during a farrowing period in a given herd varies from 0% to 100% with an average of 13.1%.

Signs and Symptoms

The disease complex can be present at farrowing time or can appear within several days after parturition. Signs or symptoms observed in the sow or gilt may include rapid breathing, depressed attitude, lack of desire to eat or drink, fever, reluctance to move about or to allow nursing. When the herdsman observes uncomfortable baby pigs, it indicates the need for closer evaluation of the sow. The mammary glands of the sow or gilt are more frequently involved than any other body part. The amount of involvement varies from only one gland to the entire udder. The affected mammary glands are usually enlarged, more firm, warmer, more sensitive, and are often discolored when compared to the other glands. Careful palpation of the mammary glands of each sow several times during the early postpartum period may reveal developing

hypogalactia and allow for treatment early in the syndrome. The presence of a purulent discharge (pus) from the birth canal does not necessarily indicate that the sow or gilt has metritis. Studies have revealed that over 60% of clinically normal sows have a discharge. Postmortem examinations of sows with agalactia have indicated that the incidence of metritis is very infrequent in this disease condition.

Tissue changes within the affected sow are variable because of the different causative agents or management factors involved. Lactation failure (agalactia) can be a primary disease or secondary to other diseases. The majority of affected animals will reveal abnormal mammary gland tissues. The changes may be characteristic of mastitis or of a partially functional gland without mastitic changes.

The area of mastitis within a gland is frequently small and has created investigator comments that the degree of mastitis could not produce the signs within the sow or the starvation in the baby pigs. The partially functional or nonfunctional gland looks and feels very similar to the gland with mastitis, which makes an accurate diagnosis difficult. The partial or nonfunctional status is believed to be the result of some insult to the hormonal sequence of events necessary to mammary gland secretion. The primary mammogens—estrogens, progesterone and prolactin—along with a number of direct and indirect synergistic hormones, are essential to full development and secretion of milk by the mammary glands. Each of these hormones must be present at the right time in the right amount to initiate and maintain lactation. Anything altering the levels of the hormones—for example, environmental stress, poor nutrition, bacterial endotoxins or improper preventive injections—can affect lactation. Other body tissue changes usually involve swelling,

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redness and possibly hemorrhages in tissues around and in the mammary glands, associated lymph glands, kidneys, synovial membranes, adrenal glands and, in some instances, the pituitary gland.

The actual cause(s) of agalactia have been narrowed from the 30-plus previously stated in the literature. All or any of those factors can be involved as contributors or stress factors that allow for mastitis to develop, sufficient endotoxin to be present, or an endocrine (hormonal) imbalance to occur which will not allow normal mammary gland function. We do not know if genetics has an important role in this disease, but stress-susceptible and stress-resistant lines have been identified and susceptible lines seem to have more agalactia problems than the stress-resistant.

Diagnosis

Diagnosis of the disease complex is usually not difficult. Proof of the cause in most instances is difficult. This disease must be differentiated from others such as transmissible gastroenteritis (TGE) or pseudorabies (Aujeszky's or PRV) to allow for the effective treatment and/or control measures to be instituted. Evaluation of history, observation of symptoms, palpation of the sow mammary glands plus postmortem examination of one or several pigs will usually allow for a definitive diagnosis.

Culturing of milk samples should be considered and, if done correctly, can reveal valuable information about a particular sow herd. Although treatments cannot be postponed until culture results are obtained, they can be changed after culture results are known if the initial treatment is not appropriate for offending organisms. Other clinical tests on an individual sow will not sufficiently enhance diagnostic efforts to be economically justified. Expanded testing when the disease involves many sows is justified to assist in determining preventive measures and in eliminating other infectious diseases. The future may reveal more rapid capabilities in determining endotoxin and endocrine levels at, it is hoped, affordable costs.

The associated veterinarian is in the best position to coordinate the diagnostic procedures in a particular herd, particularly if he/she is involved routinely in the overall swine production unit. The herdsman and the veterinarian should work together to characterize a particular situation completely and thus reach a rapid solution. An accurate diagnosis leads to treatment(s), the initiation of possible preventive measures, and the ability to make an accurate prognosis.

Prognosis

The prognosis for the life of the affected sow or gilt is good. The prognosis for the complete return or establishment of normal lactation is guarded. The affected sow usually recovers in 2-5 days with or without lactation function. Having the disease once does not mean that the sow will develop agalactia on subsequent farrowings. Unless sow lactation is rapidly re-established or supplemental feeding is successful, the chances for baby pig survival are low. The effects of chilling, diarrhea and other baby pig diseases must be fully considered.

Treatments

Affected sow treatment(s) must be directed toward establishing milk flow to aid in sustaining life of the pig while preventing secondary complications in both the sow and pig. No single treatment is superior to oxytocin, which expresses and/or releases the milk within the mammary glands which will be taken by the hungry pigs if they are

strong enough to nurse. The principle involved is no different from the often recommended frequent milking of the mastitic dairy cow for "clean out" purposes. Multiple injections of oxytocin may be necessary to provide milk for the pigs. The biological half-life of oxytocin is 6-7 minutes; therefore, injections can be given every 2-4 hours without being harmful to the sow. Timing of the injections in that manner would coincide, in part, with the normal suckling period of newborn pigs. Although oxytocin is the single, superior treatment choice, there are some agalactic sows and gilts that respond poorly or not at all to it. Reasons for the lack of response are logically tied to the cause and effect of the disease within the individual or group of sows. Research results have proved that many mammary glands are not functional; therefore, milk cannot be released.

Corticosteroids can be given to the affected sow for purposes of reducing inflammation and shortening of the recovery period. Ringarp's research efforts revealed a 7.6% increase in baby pig liveability due to use of corticosteroids with oxytocin and antibacterials.

Antibacterials should be used in treating the affected sow since there is no immediate method for determining the presence of bacterial pathogens. Use of the antibacterials does increase producer costs and forces withholding treated animals from slaughter; however, the added economic burden is justified because of the prevalence of or potential for bacterial infections.

Treatment considerations for the sow *might* also include:

- Estradiol benzoate injection to produce higher pituitary prolactin levels. Estrogens in high doses retard lactation, in some species.
- Phenothiazine derivative tranquilizer injections have a lactogenic effect through certain hormone-releasing factor changes. This has been proved *only* in man, rabbits and rats. The excitable, agalactic sow is an excellent candidate for these drugs.
- Injectable laxatives for the constipated sow are indicated. Mild, slow-acting laxatives are preferable and generally cannot be expected to enhance sow recovery in sufficient time to prevent starvation of baby pigs. Mineral oil administered via stomach tube might be considered; however, stress from the necessary restraint will be harmful.

The use of vaginal or uterine infusions, douches, or pessaries to combat suspected uterine infections may stimulate a neuro-hormonal reflex action that could result in posterior pituitary release. However, this action is not different from injecting oxytocin and, in the opinion of the authors, should not be done because of the possibility of contaminating the reproductive tract with pathogenic bacteria.

The basic sow treatments of oxytocin, corticosteroids and antibacterial agents generally produce some desirable results and are frequently the only products used.

Treatment(s) must always consider and probably include supplementary dietary support for the pigs because they have small energy storage capabilities; therefore, nourishment is critical for sustained life. Supplemental heat (85-90 F.) for the baby pigs during the first few days is energy-conserving to them and will aid in survival as a part of routine treatment or prevention.

Prevention

Prevention centers around herd health management and nutrition. The veterinarian should be thoroughly familiar with the total management practices of a particular

farm before attempting to offer suggestions for prevention of swine agalactia. The veterinarian who is consulted only when a sow is ill and not throughout the total breeding and farrowing program is handicapped in offering constructive suggestions.

Immunization procedures, if feasible, must be done in advance of anticipated problems such as bacterial mastitis. The cultures from infected sow's milk can be used to prepare a bacterin. Those herds where bacterial mastitis occurs frequently may benefit from immunization if other management practices will not overcome the problem.

Efforts to reduce stress throughout gestation, especially near parturition, are important preventive measures. An example would be sow acclimatization to the farrowing facility. Use of a new or remodeled farrowing house for the first time frequently brings about agalactia in some sows. One could also wonder about acclimatization of the herdsman owing to the fact that some "outbreaks" are thought to have been human-induced by noise factors, schedule irregularities, etc.

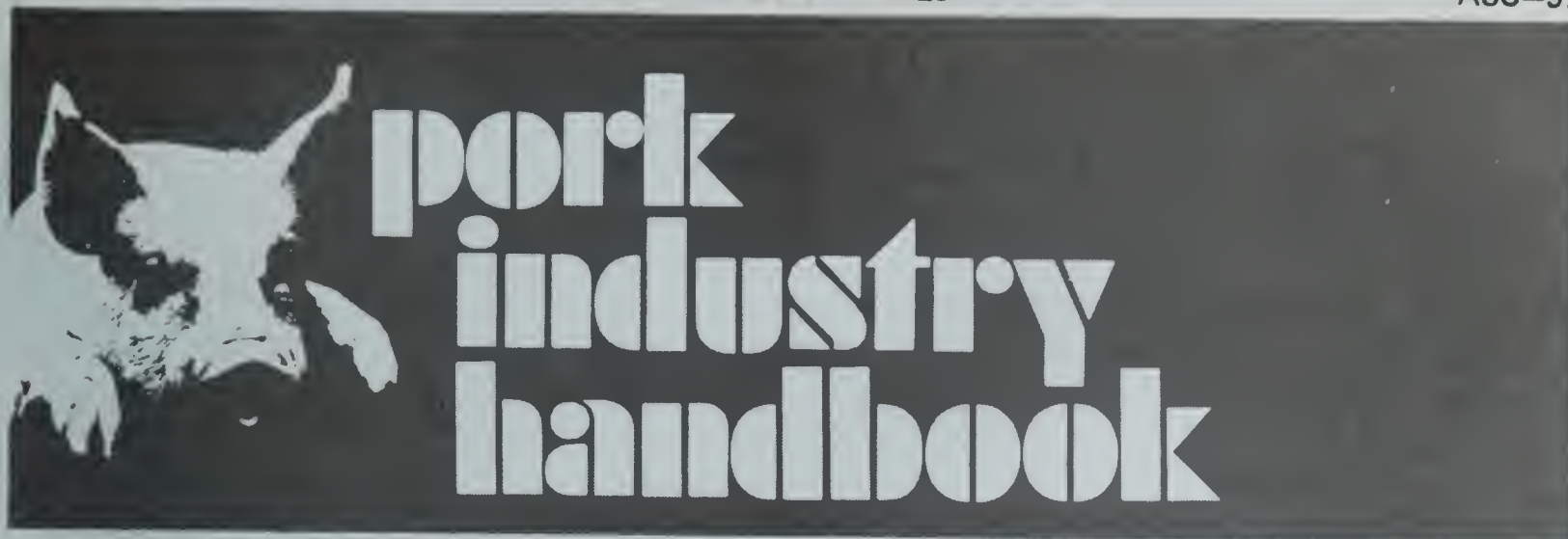
Gestational feeding of sows and gilts has an influence on incidence of agalactia. The underfed sow apparently cannot maintain blood glucose levels as well as the adequately fed sow; therefore, resistance may be lower. Pork Industry Handbook (PIH) 23, concerning gestation

and lactation rations, should be consulted. Ration substitutes are given if constipation is a problem. Additives to reduce mammary gland edema might be considered in some herds. The mixture of 12 parts potassium nitrate NF, 4 parts methenamine USP, and 1 part dicalcium phosphate by weight, given at the rate of 1 oz. twice daily 1 week prior to and 1 week following farrowing may be helpful.

Management attention to controllable environmental factors in the farrowing house is commanded. High humidity and temperature around the sow or gilt should be avoided. Provisions for heat lamps, heat pads, etc., should be available for the baby pigs, but away from the sow.

Preventive research efforts related to various drugs and hormones fed and/or injected prior to farrowing have occasionally produced excellent clinical results. However, critical evaluations and continued study prove that what works in one herd may have no value in another. The future may reveal the usefulness of prostaglandins in agalactia prevention. This parahormone is not approved for use in food animals in the United States at this time.

Swine agalactia is a complex disease syndrome requiring much consideration and effort to produce acceptable results in prevention and/or treatment within the industry. Research efforts are continuing, and newer knowledge will be reported as learned.



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Mycoplasmal Pneumonia and Other Mycoplasmal Diseases of Swine

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Swine producers are often confused by the complexity of the mycoplasmal infections. This fact sheet is an attempt to clarify the information that is currently available about these swine diseases. There are three recognized *Mycoplasma* spp. of bacteria that cause disease in pigs—*Mycoplasma hyopneumoniae*, *Mycoplasma hyorhinis* and *Mycoplasma hyosynoviae*.

Mycoplasmal Pneumonia

Mycoplasmal pneumonia (in the U.S.) or porcine enzootic pneumonia (England and other countries) is caused by *Mycoplasma hyopneumoniae*. Another synonym for this disease is swine enzootic pneumonia (SEP). Fifteen years ago this disease was called virus pneumonia of pigs (VPP); since that time it has been discovered that a mycoplasma, not a virus, is the cause. Mycoplasma are very small and readily pass through ordinary bacterial filters. In addition, mycoplasma are difficult to grow in the laboratory. For these reasons, it was originally assumed that mycoplasmal pneumonia was a virus.

Mycoplasmal pneumonia affects pigs of all ages, starting with those as young as 7-10 days of age. It is estimated that 90% or more of the swine herds in the midwestern United States are infected with mycoplasmal pneumonia.

Mycoplasmal pneumonia is a chronic disease. A high percentage of the pigs are affected, but the death loss is

low. Pigs usually show first signs of the disease between 3 and 10 weeks of age. The incubation period is 10 days or more after exposure to carrier swine. The pigs have a dry, nonproductive cough that is most noticeable after exercise. Pigs may cough for only 1-3 weeks, or the coughing may persist indefinitely. Other conditions such as influenza, pasteurella pneumonia and lungworms also cause pigs to cough and should be considered in making a differential diagnosis.

In general, pigs with mycoplasmal pneumonia continue to eat reasonably well, but some do not grow at a normal rate if lesions are extensive or secondary bacterial pneumonias occur. Severe pneumonia also results when mycoplasmal pneumonia is complicated by large numbers of ascarid (roundworm) larvae passing through the lungs. Pigs are also more severely affected when lungworms are present. Growth retardation due to mycoplasmal pneumonia is variable. Generally, the more severe the lesions the greater the effect.

Adequate treatment of established mycoplasmal pneumonia is not currently available. Several promising treatments are being investigated. Sulfas and antibiotics are very useful in the control of secondary bacterial pneumonias. Good nutrition, a warm, dry, dust- and draft-free environment and ascarid and lungworm control programs are useful in minimizing the effects of mycoplasmal pneumonia. Uncomplicated lesions may heal in 55-60 days without treatment.

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Mycoplasmal Polyserositis-Arthritis

A second mycoplasma affecting pigs is *Mycoplasma hyorhinis*. This organism causes arthritis and inflammation of the lining of the chest and abdominal cavity and the membrane which covers the heart. In addition, the membranes around the testicles of male pigs are often affected. Pigs weighing from 15 to 60 lb. are most commonly affected. The producer may notice lameness and an unthrifty appearance, but no coughing. He may occasionally find a pig that has died suddenly. A veterinarian making a postmortem examination may find typical lesions around the lungs, the heart or in the abdominal cavity.

There is no satisfactory treatment on an individual basis. Herd treatment with injectable tylosin or lincomycin may be beneficial in the early stages of the disease.

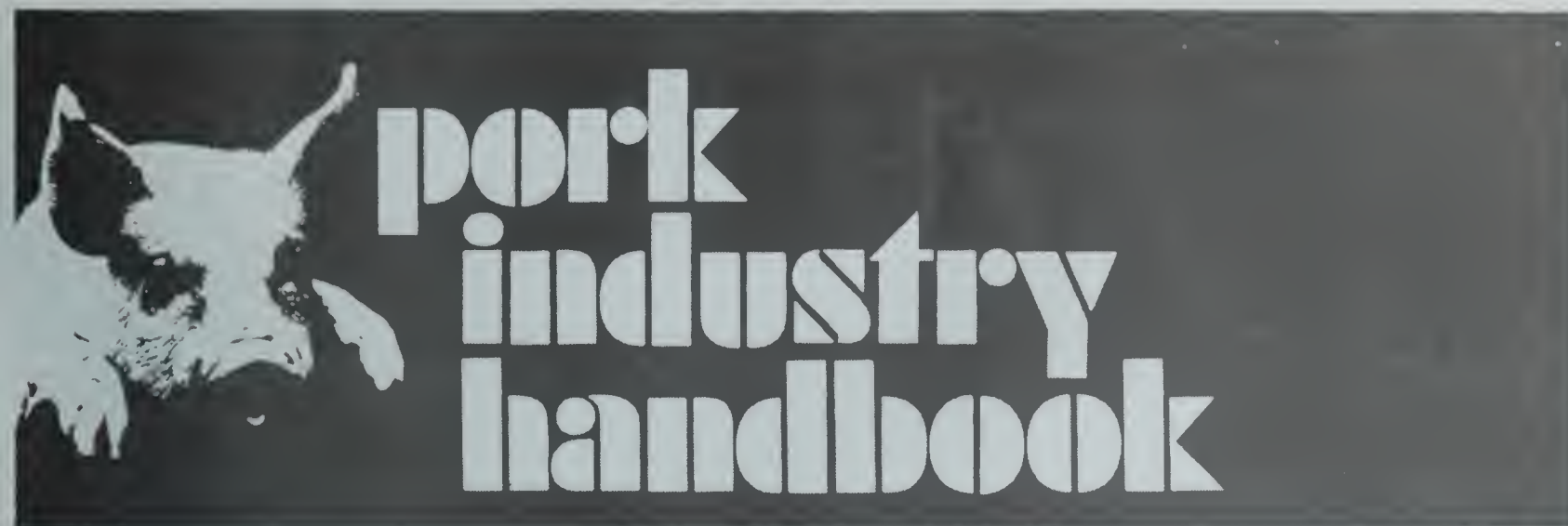
Mycoplasmal Arthritis

The third mycoplasma, *Mycoplasma hyosynoviae*, causes arthritis in larger pigs weighing 90-220 lb. This disease seems to affect pastured pigs more often than pigs raised on concrete. In a typical case, a wave of arthritis goes through the group following a period of stress such as regrouping of pigs or cold wet weather. Many of the pigs become very lame with swollen hock, elbow, shoulder or stifle joints.

Mycoplasma hyosynoviae often affects new animals such as boars being introduced into an infected herd. New additions to the herd pick up the mycoplasma from apparently healthy carrier animals already in the herd. These animals often carry the organisms in their tonsils for many months with no apparent effects. Swine producers having herds known to be infected are often advised by veterinarians to inject tylosin or lincomycin into new animals being added to the herd to prevent infection and the lameness that follows.

Injectable tylosin or lincomycin given during the first 24 hours of the acute stage and repeated daily for 2-3 days usually gives a satisfactory response. In addition, a single injection of a corticosteroid reduces the pain and inflammation but should be given only one time as repeated injections lower resistance to infections. Feed and water forms of tylosin are poorly absorbed and are not effective as a treatment.

The only method of eliminating mycoplasmal infections from a swine herd is through depopulation and restocking with animals known to be free of these diseases. Because the mycoplasmal diseases are some of the major disease problems in U.S. swine, much additional research is needed in this area. A high priority should be given to developing reliable control programs for swine mycoplasmal diseases.



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Infectious Swine Reproductive Diseases

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This fact sheet reviews the major infectious diseases capable of reducing reproductive efficiency in swine. It discusses cause, clinical signs, diagnosis and control of viral and bacterial diseases in both sows and boars.

Viral Diseases

Viral reproductive disease in swine has, for the last ten years, been loosely categorized under the acronym SMEDI, referring to stillbirths, mummified fetuses, embryonic deaths and infertility. Although this term was useful for understanding the varied effects of viruses on swine reproduction, it is no longer a desirable term. Knowledge of the specific viruses and their effects on reproduction has increased substantially; the scientific community and pork producers, therefore, should discuss the diseases caused by specific viruses.

South Dakota researchers recently reported that viruses most commonly isolated from aborted swine fetuses were enteroviruses, parvovirus, adenovirus and reovirus.

Parvovirus

The virus currently causing the greatest concern in swine reproductive failure is the porcine parvovirus. When susceptible gilts or sows are infected with parvovirus during the first month of gestation, fetal death and resorption of fetal tissue can result. These infected females return to heat and may be identified as repeat breeders. Infection during the second month of pregnancy usually results in mummified fetuses. Part or all of the pigs may become mummified. Parvovirus infection usually does not result in death of all the fetuses at the same time; therefore, mummies of different sizes may be seen within the litter. Slaughterhouse studies have shown that most of the mummified pigs are the result of the porcine parvovirus and that the virus is often responsible for small litters. Abortion is seldom seen with parvovirus infection. If infection occurs during the late stages of pregnancy, the fetuses seem resistant to the effects of parvovirus.

Herd outbreaks of parvovirus infection are characterized by small litters and increased mummified pigs. Repeat breeding is a common sign of infection, but without

mummified fetuses to sample, the disease is difficult to diagnose.

Diagnosis is best achieved by submitting mummified fetuses to diagnostic laboratories for direct fluorescent antibody testing. Fortunately, the parvovirus persists for long periods of time in the mummified pig. Blood tests are available for determining evidence of previous exposure to parvovirus, but they have limited value because they do not determine the time of parvovirus infection.

Preventing parvovirus infection is difficult. Clinical observation suggests that the traditional method of mixing sows, gilts and boars is not always effective in establishing a common protection against the disease. Until more knowledge is available, however, management of the gilts to encourage natural exposure to the virus is recommended. New evidence from Australia suggests that withholding gilts from breeding until they reach 10 months of age helps prevent parvovirus infection. By that time, most gilts are actively immunized to the disease. Vaccines, designed to hasten the time that gilts develop active protection against parvovirus, are currently being studied. None is currently federally licensed for use.

Other Viruses

Researchers have reported that another group of viruses called enteroviruses can cause reproductive failure in pigs. Inoculation of gilts with these viruses during early gestation can cause embryonic deaths and returns to heat. Experimental enteroviral infection has also been manifested by fetal mummification and stillborn pigs. Even though experimental studies have shown that enteroviruses can cause reproductive failure, the scientific literature contains few reports of naturally occurring enteroviral reproductive disease. There is no additional evidence that enteroviral reproductive disease is of major economic importance. In the author's experience, nearly all United States swine prior to breeding age already have antibodies that presumably offer protection against all of the strains of enteroviruses. Very little is known about the prevalence or the economic seriousness of other viruses that reduce reproductive performance.

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Bacterial Disease—Leptospirosis

Porcine leptospirosis usually causes abortion, stillbirths and low baby pig survival. Leptospirosis should always be suspected when reproductive failure is being investigated. In the United States, the 4 most troublesome serotypes of leptospirae in swine are: *L. pomona*, *L. grippityphosa*, *L. canicola*, and *L. icterohaemorrhagiae*. *L. pomona* is the most important cause of swine leptospirosis throughout the world, but within specific areas other serotypes may be prevalent.

The incubation period for leptospirosis is usually 1 - 2 weeks. The acute illness includes only a moderate fever and loss of appetite in the breeding herd. The leptospirae are present in the urine ten days after the onset of acute illness and are sometimes detectable for up to 12 months. Reproductive failure is not manifested until approximately 10 days after acute infection.

The stage of pregnancy is an important factor in determining the clinical signs of leptospirosis. There are no effects on the embryo when infection occurs during the first month of pregnancy. Infection during the second month of pregnancy may cause fetal death and resorption, mummification or abortion. During the third month of gestation, infection usually causes abortion.

Common sources of leptospirae include infected urine, contaminated surface water and direct contact with urine of shedder animals, and infected tissues such as the carcasses of rodents. Leptospiral organisms can enter the body through the skin or the mucous membranes. Because swine can shed large numbers of organisms over an extended period of time, they are a serious threat to adjacent animals and to humans.

Leptospirosis is diagnosed on the basis of herd history, post mortem findings, and blood tests. The herd history must consider vaccination schedules, methods for leptospirosis testing of new stock entering the herd, and exposure of the herd to wildlife, including skunks, cats, raccoons, opossums, dogs and rats that may be vectors for the various strains of leptospirae. The best diagnosis of leptospirosis can be achieved by measuring antibodies from a sample of serum from infected dams. Because the acute disease usually precedes the observed reproductive failure by about 10 days, antibodies to leptospiral organisms are usually detectable at the time of the observed reproductive failure. Many laboratories also use fluorescent antibody techniques to help diagnose leptospirosis.

Control of leptospirosis is usually based on a vaccination program and the isolation of the herd from the source of the organisms. Breeding swine should be vaccinated with bacterins for each pathogenic leptospiral serotype prevalent in the geographic area. To assure continued protection, bacterin injection should be repeated every six months or prior to every breeding. Confinement of the breeding herd reduces exposure to wildlife and substantially reduces the probability of leptospirosis. Blood testing new additions to the herd and eliminating positive animals is a method of reducing the likelihood of introducing leptospirosis into a herd.

Brucellosis

Although the incidence of swine brucellosis has decreased markedly during the past two decades, it remains a cause of abortion and infertility. The disease caused by *Brucella suis* is usually spread by ingestion of the organism, although it can be transmitted venereally. Sterility or infertility may be the only manifestation of brucellosis. Infertility is usually the result of unobserved abortions or fetal resorptions. The cause of infertility in sows appears to be a persistent metritis. The incidence of abortion is usually less than 30% of the breeding herd in naturally occurring brucellosis. The average time of abortion with brucellosis infection is about 70 days of gestation. In the boar, brucellosis can cause sterility and reduced fertility. A positive diagnosis of brucellosis can be made using the standard card test on the serum of sows or boars.

The best control method is to eradicate the disease by purchasing breeding stock from validated brucellosis-free herds, by testing incoming breeding animals, and by eliminating positive animals from infected herds.

Eperythrozoonosis

Eperythrozoonosis is a small parasite of red blood cells. Because of a newly-developed serum test, veterinarians are more capable of diagnosing this infection. Even though very little scientific information is available, the following clinical entities have been reported to be associated with high titers against eperythrozoonosis: failure to exhibit behavioral estrus, repeat breeding, occasional abortion, prolonged farrowing, agalactia (no milk), weak, anemic pigs at birth, hemorrhagic deaths of newborn pigs, slow growth of pigs and acute deaths in growing pigs.

Notice that these signs are similar to many other diseases. Differential diagnosis is imperative to avoid over-diagnosing eperythrozoonosis. Diagnosis should be based on clinical signs, serum titers, or the detection of the parasite in blood smears. Although determining serum titers helps confirm the diagnosis, the following statements indicate the inaccuracy of basing the diagnosis entirely on titers:

1. About 20% of all herds are seropositive for eperythrozoonosis.
2. When titers are detectable, they are almost always in adult animals. Pigs under 6 months of age are likely to be seronegative.
3. Within a positive herd, there is a very poor correlation between animals with high titers and the clinical signs mentioned above.

Because of the uncertainty regarding eperythrozoonosis, the following course of action seems warranted:

1. Test each breeding herd semiannually. At least 10 adult boars and sows should be sampled. An increasing number of diagnostic laboratories are capable of conducting the newly-developed serum test.
2. Control mange. Mange infection can mimic many of the signs of eperythrozoonosis. Contrary to published reports, spraying for mange for 6 consecutive weeks will not eradicate sarcoptic mange. An alternative program is to spray the first and second Fridays of every month.
3. There is scientific evidence that arsanilic acid helps limit the signs of eperythrozoonosis; tetracycline and lincomycin have not been shown to be effective.

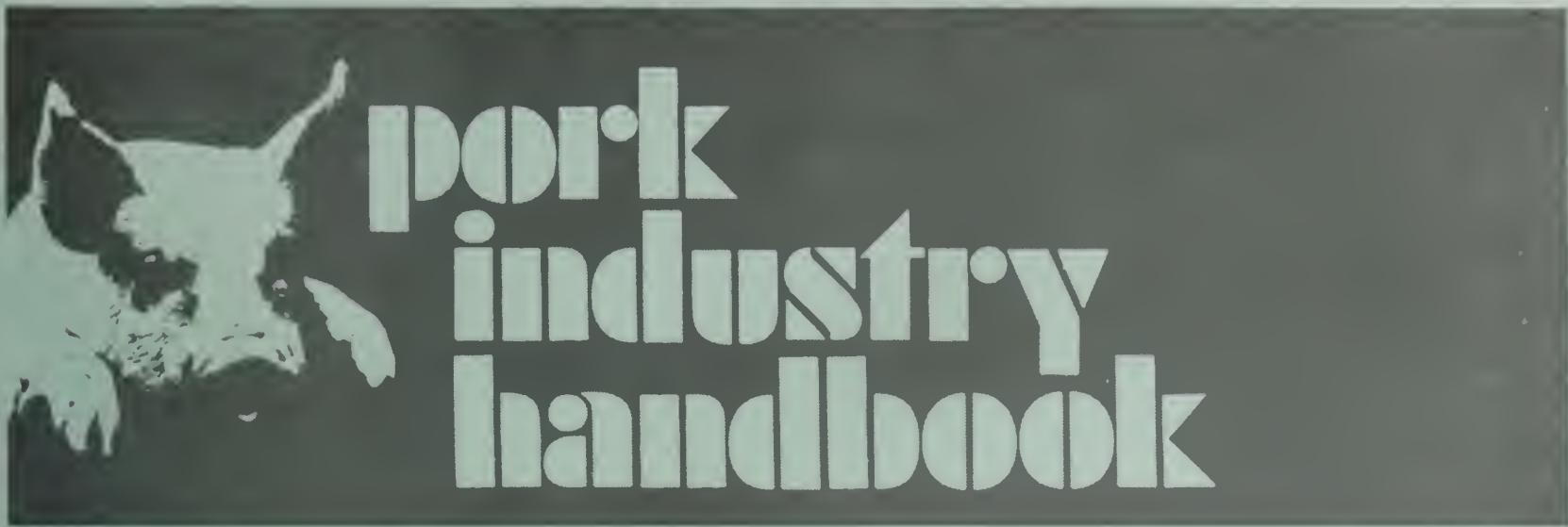
Whenever repeat breeding, mummified fetuses, still-born pigs, small litters or weak pigs are observed, infectious reproductive disease should be considered. Fetal specimens should be gathered as quickly and cleanly as possible and refrigerated or taken directly to your veterinarian or diagnostic laboratory. Additionally, veterinarians are advised to submit maternal blood samples for diagnostic testing. Diagnosis is essential for establishing effective control or preventive measures.

Diseases of Boars

Boar fertility is likely to be reduced whenever boars have any disease that results in fever. Likely causes of fever in breeding boars include pseudorabies, brucellosis, erysipelas and influenza. If fever occurs and fertility is reduced, it is not likely to return to normal until about 2 months after the infection.

Several researchers have shown that high ambient temperatures can reduce fertility. Extended exposure to temperatures of 90 F. results in lowered fertility that does not return to normal until about 2 months later.

The role of the boar in disease transmission is poorly studied. Brucellosis, pseudorabies and parvovirus organisms have all been isolated from boar semen. While the boar is thought to be a primary vector in brucellosis transmission, the role of the boar in pseudorabies and parvovirus transmission is unclear. Artificial insemination, therefore, may also serve as a mechanism for disease transfer.



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Protein and Amino Acids for Swine

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No pig can develop lean tissue (muscle) to its genetic potential nor can a sow realize her maximum reproductive potential unless their diets contain sufficient protein with the correct amino acid composition. Protein is made up of many sub-units called amino acids. During the digestive process, proteins are broken down into individual amino acids. The animal absorbs amino acids from the intestines and recombines them within the body tissue into new protein molecules. Each of the body proteins are synthesized by the amino acids joining together in a pre-established sequence dictated by the genetic background of the animal.

Muscle protein is composed of about 22 different amino acids. Ten of these amino acids must be supplied in the pig's diet; the others can be synthesized in the body rapidly enough for maximum growth if a source of dietary nitrogen and adequate energy are present. The 10 that must be supplied in the diet are called *essential* amino acids; the others are classified *non-essential*. The 10 essential amino acids required by swine include: arginine, histidine, isoleucine, leucine, lysine, methionine + cystine, phenylalanine + tyrosine, threonine, tryptophan and valine.

Actually, swine do not have a protein requirement per se, but rather they have a dietary requirement for:

1. Non-specific nitrogen to synthesize the non-essential amino acids.
2. Specific amounts of the essential amino acids.

Any diet formulated from natural feedstuffs that

satisfies the second requirement will automatically satisfy the need for non-specific nitrogen. Even though the pig does not have a specific protein requirement, most ration formulators have attempted to meet the amino acid requirements simply by feeding prescribed protein levels. Most rations will meet this objective *if* high quality protein feeds are used with the cereal grains.

Protein synthesis is an "all or nothing" type of synthesis. If any one of the essential amino acids needed to form a protein is deficient, that protein cannot be formed. Nothing explains the concept of limiting amino acids better than the age-old illustration that likens a protein to a wooden barrel made up of rings and staves. The amino acids are the staves, and since a barrel will only hold water to the height of its lowest stave, a protein will only allow the pig to lay down meat to the extent of the amino acid present in the least amount. This amino acid, the shortest stave in the protein barrel, is called the *first-limiting amino acid*, the next in shortest supply, the *second-limiting amino acid* and so on. Therefore, *quality of protein* (presence and amount of the 10 essential amino acids) is more important than the total amount of protein fed.

Several principles of protein-amino acid nutrition are illustrated in the results of a 21-day feeding trial conducted with young pigs averaging approximately 20 lb. initially. Two different high protein sources (soybean and peanut meal) plus supplemental lysine were used in the sorghum-based diets.

Diet			Pig performance			
No.	Type of diet	Dietary lysine	Dietary protein	Daily gain	Daily feed intake	Gain/feed
		percent			pound	
1.	Sorghum-soybean meal	1.07	20.2	1.19	2.28	.52
2.	Sorghum-peanut meal	.54	20.2	.55	1.54	.36
3.	As 2 + lysine	1.07	20.2	.92	2.23	.41
4.	Sorghum-peanut meal	1.07	40.0	.68	1.55	.44

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The control diet consisted of sorghum and soybean meal which was formulated to provide 1.07% lysine, which is 110% of the N.R.C. lysine recommendation for this weight pig. To obtain the level of lysine desired, enough soybean meal was added to give a 20.2% protein diet. When sorghum and peanut meal were used to achieve the same protein level (diet 2), lysine was severely deficient and the average daily gain and gain/feed were greatly reduced compared to those on diet 1. This was due to its *lower percentage of lysine* (the first-limiting amino acid) and less feed consumption as compared to diet 1. The low feed intake for diet 2 is attributed to the *lysine deficiency* and/or *amino acid imbalance*.

In the formulation of diet 3, supplemental lysine was added to the 20.2% peanut meal diet (diet 2) to give the same lysine level as in diet 1 (1.07%). Feed intake, daily gain and gain/feed were higher on diet 3 than on diet 2, which clearly demonstrates that lysine was the first limiting amino acid in diet 2. However, the average daily gain of pigs fed diet 3 was less than those supported by diet 1 (.92 vs 1.19 lb./day). This suggests that *other amino acids* (in addition to lysine) are deficient in diet 3 compared to diet 1.

In diet 4, the same dietary level of lysine as in diet 1 and 3 was achieved by adjusting the sorghum-peanut meal ratio. Gain performance, while better than that achieved by pigs fed diet 2, was much lower than for pigs fed diet 3 (.92 vs .68 lb./day). Therefore, feeding more of a lysine-deficient protein, such as peanut meal, is an inefficient means of meeting the dietary need for lysine. These results also suggest that the high percentage of peanut meal used in diet 4 resulted in an *amino acid imbalance*.

Other important concepts of protein-amino acid nutrition of swine that have been firmly established through controlled research include the following:

1. Amino acid requirements expressed as a percent of the diet are a function of:

- Age, weight and function of animal
 - Decrease with age and weight.
 - Higher for lactation than gestation.
- Protein content of diet
 - Requirement for a specific amino acid increases as dietary protein level increases and decreases as dietary protein level decreases.
- Caloric density of diet
 - Increases as energy level increases.
- Meatiness and sex
 - Higher for more muscular animals.
 - Higher for gilts than barrows.
- Interrelationship among amino acids
 - Cystine can furnish at least 50% of the requirement for total sulfur-bearing amino acids (methionine + cystine).
 - Tyrosine can provide about 30% of the phenylalanine requirement.
 - Methionine in excess can completely eliminate the dietary need for choline (B-vitamin); however, the reverse is not true, excessive choline does not lower the requirement for methionine.
 - Tryptophan can be converted to the essential B-vitamin, niacin, but the conversion is inefficient (e.g., 50 gm. tryptophan will yield only 1 gm. of niacin). The reverse reaction does not occur (niacin cannot be converted to tryptophan).
 - Excess lysine in the diet increases the requirement for arginine.
 - Excess leucine increases the requirements for valine and isoleucine.
 - Excess methionine increases the requirement for threonine.

2. Regardless of sex, maximal carcass leanness requires a higher level of dietary amino acids than maximal rate of gain.

3. A diet with a good amino acid balance, even though it is below the traditional level in total protein and essential amino acids, has little or no depressing effect on voluntary feed intake. However, a deficiency of even one amino acid or an imbalance of amino acids (excess of one or more in relation to others) will cause a reduction in feed intake and daily gains.

4. Pigs utilize the L-isomers of all amino acids (L-isomers are present in natural feedstuffs) but only utilize the D-isomers of methionine and tryptophan effectively. D-methionine is equal to L-methionine; D-tryptophan has about 60% of the biological value of L-tryptophan.

These concepts provide guidelines that must be considered when attempting to generalize about the protein and amino acid needs of swine to optimize reproductive efficiency, feedlot performance, carcass merit and production costs.

Amino Acid Requirements

The requirements for the 10 essential amino acids during various stages of the growing-finishing period recommended by the National Research Council are given in Table 1. These reflect averages for published data that were found to be needed for normal health and performance of experimental animals. They do not include a safety factor; therefore, persons applying these standards may need to increase the levels of certain amino acids to meet specific conditions. Most of these requirements have been established using corn-soybean meal diets; hence they may need modification as other feed ingredients are used, especially as it relates to amino acid availability.

Please note that the amino acid requirements, expressed as a percent of the diet, decrease as a pig becomes heavier. Requirements are greatest during the rapidly growing stages of the young animal. Not only is the young animal growing at a more rapid rate (greater percentage increase in body weight per day) but also the proportion of protein in the weight gain is higher than during the finishing period. These changes in rate of growth and body composition are the basis for recommending different dietary protein levels to meet the amino acid requirements during the life of the pig.

Although the exact needs for some amino acids required for optimum reproduction are still in question, intensive research in the past decade has provided excellent guidelines for maintenance, gestation and lactation (Table 2). Illinois workers reported the maintenance requirements in 1966 and later provided evidence that the requirements during gestation could be divided into two periods (first 80 days of gestation, days 80-114 of gestation). It appears that a vitamin- and mineral-fortified corn or sorghum diet may be sufficient during early gestation, but it is inadequate during the last trimester of pregnancy when fetal growth is most rapid. Feeding the low level throughout gestation does not affect farrowing performance but will not support optimal lactation performance of the dam as shown by reduced litter weaning weights. This is the basis for listing the gestation requirements for the first two-thirds and for the last one-third of pregnancy.

The amino acid requirements for lactation are less well defined than those for gestation, but great progress has been made in the last few years. Illinois workers first estimated the essential amino acid requirements for the lactating sow in 1969. Since 1971, Iowa State workers have determined the lysine, total sulfur amino acids, threonine,

tryptophan, leucine and isoleucine requirements for lactating sows. Using the Illinois estimates and calculations from their experiments, Iowa workers have suggested the requirements for the first, second and third reproductive cycles that are given in Table 2. Fortunately, the requirements for the amino acids that have been determined have agreed reasonably well with the calculated estimates. The daily quantitative requirements for individual amino acids have varied greatly because of the wide variation in milk production and milk composition. However, recent research suggests that the percent levels of lysine shown in Table 2 for lactating sows is usually adequate, provided that feed intake is proportional to her milk production potential.

The amino acid requirements for maintenance are less than during gestation, and gestation requirements are lower than for lactation (Table 2). Recent research has clearly demonstrated that swine have a remarkable capacity to buffer their offspring against a dietary protein or amino acid deficiency. It is apparent that pregnant and lactating swine can successfully carry out their intended functions of producing large, healthy pigs at weaning on substantially lower intakes of protein and amino acids than formerly thought possible.

Amino Acids in Grain

Although cereal grains are used primarily as sources of energy in a swine ration, they also contribute protein and amino acids to the diet. The essential amino acid composition of today's corn and sorghum hybrids are quite similar (Table 3). Compared to the young pig's (40 lb.) requirement, lysine is the first-limiting amino acid in both grains, although experiments with corn have revealed that tryptophan, perhaps due to a lower availability, is more limiting than lysine. For the 40-lb. pig, both grains contain adequate levels of arginine, histidine, leucine and phenylalanine + tyrosine, while both are deficient in tryptophan, threonine, sulfur-bearing amino acids and isoleucine.

Oats, wheat and barley are somewhat higher in protein than corn, but they contribute little more toward meeting the amino acid requirements of the growing pig since they are also deficient in lysine, threonine, isoleucine and the sulfur-amino acids. However, all of these grains contain more lysine than corn and sorghum. Hence, slightly less high quality protein supplement is required in formulating diets containing these grains. One practical way to allow for this slightly superior amino acid balance (when formulating diets on a percent protein basis) is to figure these grains at 11.0% protein as compared to 9% for corn and sorghum. Even though sorghum generally contains slightly more protein than corn, the same amount of protein supplement must be fed with sorghum as corn because the level of lysine is usually slightly lower for sorghum than corn (Table 3). Because of its relatively high level of crude fiber, oats should generally not comprise more than 25% of a swine diet.

Opaque-2 corn is richer in lysine and tryptophan than regular hybrid corn. Its protein level is similar to regular corn. Decisions concerning when to use *opaque-2* corn in swine rations should be made on the basis of economics, yield characteristics and lysine content of the particular varieties available. Several recent studies have shown that commercially available *opaque-2* corn contains between 30 and 50% more lysine and tryptophan than regular corn.

Amino Acids in High Protein Feedstuffs

Since lysine, tryptophan, threonine, isoleucine and the sulfur-bearing amino acids are the most deficient in corn and sorghum, high protein feedstuffs should be evaluated

primarily on their ability to correct these deficiencies, particularly that of lysine. Table 4 gives the lysine, tryptophan, threonine, isoleucine and methionine + cystine values in several high protein feeds. Since high protein feedstuffs vary so widely in percentage of protein (85% for feather meal, 12% for dried whole whey) the *amino acid content expressed as a percent of protein* is a more accurate yardstick to use in evaluating the ability of a protein source to correct the amino acid deficiencies of grain than the percentage of amino acid in the feedstuff. In formulating a 16% grower diet from corn or sorghum using a 38% protein supplement, the supplement must contain (as a percent of the protein) the minimum or higher amounts of the following amino acids: lysine, 6.25%; tryptophan, .66%; threonine, 2.41%; isoleucine, 2.74%; methionine + cystine, 2.74%.

The values given in Table 4 show that only fishmeal and dry buttermilk satisfy all the requirements. Dried whole whey and soybean meal appear to be marginal in the sulfur-bearing amino acids. However, methionine additions to corn-soybean meal or sorghum-soybean meal diets have failed to improve performance. Hence, fish meal, dry buttermilk, whole dried whey or soybean meal would appear to provide an amino acid balance that complements and corrects the deficiencies of corn and sorghum. Of these, however, soybean meal is the only protein source that results in optimal performance when combined with grain. The available tryptophan content of fish meal may be its limiting factor, while the lactose content of dried whey and buttermilk would limit its use, especially for pigs beyond 8 weeks of age. Moreover, the supply and price of fish meal and the milk products prevent their routine use in swine feeds.

Tankage (meat meal) contains sufficient lysine, but tryptophan and the sulfur amino acids are marginal. Meat and bone meal is limiting in both tryptophan and lysine. Meat products such as these are high in ash and therefore less palatable. They should not comprise more than 3-5% of the complete ration.

Several of the high protein feeds in Table 4 are lysine-deficient including cottonseed meal, peanut meal, feather meal, corn gluten and sorghum gluten meals. Cottonseed and peanut meals can be used effectively to provide a portion of the protein supplement, but they must be fed in combination with other high protein feedstuffs that have a high lysine content to obtain maximum performance.

At current prices, soybean meal is the high protein feed of choice to correct the amino acid deficiencies of grain.

Use of Synthetic Amino Acids

The protein shortage of 1972-73 stimulated research and practical demonstrations that more adequately defined the role that synthetic lysine can play in swine feeding. Unfortunately, lysine and methionine are the only two essential amino acids available today in the feed-grade form. However, there are indications that feed-grade tryptophan and threonine will be commercially available in the next few years.

Although the world's annual production is limited, feed-grade lysine has been used in swine feeds for several years. Its price in relation to the cost of lysine in high protein feedstuffs has limited its use except when high protein feeds are unusually expensive. However, research has clearly demonstrated that supplemental lysine can significantly reduce the amount of high quality soybean meal needed in swine diets. Theoretically, ration formulators only need to add enough soybean meal to meet the requirement for the second-limiting amino acid, then add enough synthetic lysine to meet the lysine requirement. Feedlot performance on the lower-protein

Table 1. Amino acid requirements for growing-finishing swine at various weights*

Amino acids	Pig weight, lb.				
	10-22	22-44	44-77	77-132	132-220
	percent of diet				
Arginine	.28	.23	.20	.18	.16
Histidine	.25	.20	.18	.16	.15
Isoleucine	.69	.56	.50	.44	.41
Leucine	.83	.68	.60	.52	.48
Lysine	.96	.79	.70	.61	.57
Methionine + cystine†	.60	.55	.50	.40	.30
Phenylalanine + tyrosine‡	.69	.56	.50	.44	.41
Threonine	.62	.51	.45	.39	.37
Tryptophan	.18	.15	.13	.11	.11
Valine	.69	.56	.50	.44	.41

*N.R.C. 1973. Nutrient Requirements of Domestic Animals, No. 2. Nutrient Requirements of Swine. National Research Council, Washington, D.C. Methionine + cystine requirements have been adjusted to reflect information published after 1973.

† Methionine can fulfill the total requirement; cystine can supply at least 50% of the total requirement.

‡ Phenylalanine can fulfill the total requirement; tyrosine can fulfill 30% of the total requirement.

Table 2. Amino acid requirement (percent of diet) of adult female swine.

Item	Maintenance*	Gestation*		Lactation†		
		Days 0-80	Days 81-114	Gilt	2nd litter	3rd litter or more
Feed intake, lb./day	4	4	4	9	10	12
Crude protein	3.0	9.0	12.0	14.0	14.0	14.0
Amino acids						
Arginine	0	---	---	.39	.43	.41
Histidine	0	.10	.17	.22	.24	.23
Isoleucine	.07	.22	.37	.34	.37	.35
Leucine	.04	.33	.56	.65	.71	.68
Lysine	.06	.25	.42	.59	.64	.61
Methionine + cystine	.06	.17	.28	.26	.28	.27
Phenylalanine + tyrosine	.05	.18	.30	.67	.73	.71
Threonine	.09	.20	.34	.36	.38	.37
Tryptophan	.01	.04	.07	.10	.11	.11
Valine	.05	.27	.46	.41	.44	.43

*Baker, D. H., and coworkers, University of Illinois.

† Speer, V. C., and coworkers, Iowa State University.

Table 3. Essential amino acid content of commonly used swine feeds.*

	Protein	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Cystine	Phenylalanine	Tyrosine	Threonine	Tryptophan	Valine
	percent												
Grains													
Corn†	8.8	.42	.24	.31	.98	.26	.19	.20	.41	.35	.32	.09	.46
Sorghum‡	9.0	.36	.21	.38	1.13	.22	.17	.14	.46	.37	.29	.09	.70
Barley§	11.7	.58	.27	.54	.81	.36	.18	.19	.63	.36	.36	.16	.63
Corn, high lysine#	8.5	.53	.28	.27	.70	.37	.16	.18	.35	.27	.31	-----	.41
Oats§	12.0	.58	.15	.39	.66	.34	.18	.15	.39	.60	.33	.13	.46
Wheat§	12.2	.60	.28	.46	.88	.38	.20	.16	.62	.38	.37	.15	.55
Protein Sources§													
Soybean meal	44	3.20	1.21	2.32	3.62	2.88	.56	.66	2.35	1.46	1.87	.55	2.31
Soybean meal	50	3.54	1.30	2.49	3.88	3.14	.73	.82	2.52	1.56	2.00	.63	2.48
Alfalfa meal, dehydrated	17	.94	.29	.72	1.09	.80	.29	.29	.72	.43	.58	.36	.80
Blood meal	80	3.20	3.79	.88	9.89	5.37	1.04	1.40	5.17	1.78	3.87	1.02	6.91
Buttermilk, dry	32	1.08	.80	2.17	3.13	2.20	.72	.41	1.43	1.01	1.46	.47	2.40
Cottonseed meal, solvent	41	4.27	1.00	1.18	2.12	1.55	.49	.65	1.96	1.03	1.19	.48	1.60
Distillers dried solubles (corn)	27	1.03	.70	1.72	2.21	.77	.50	.36	1.72	.61	1.01	.18	1.61
Fish meal (menhaden)	60	4.06	1.55	2.99	4.79	4.60	1.88	.62	2.65	2.14	2.67	.71	3.42
Meat & bone meal	50	3.59	.90	1.71	3.12	2.50	.65	.62	1.81	.84	1.81	.29	2.42
Peanut meal, expeller	50	5.23	.94	1.47	2.62	1.35	.54	.34	2.17	1.72	1.13	.48	2.72
Tankage (meat meal)	60	3.69	1.95	1.95	5.26	3.89	.75	.52	2.78	.96	2.48	.58	4.32
Wheat bran	15	.95	.29	.56	.85	.56	.09	.29	.47	.38	.38	.29	.66
Wheat midds, standard	16	.83	.37	.73	1.10	.64	.16	.18	.63	.37	.54	.18	.73
Whey, dried whole	12	.27	.16	.72	1.00	.80	.16	.24	.28	.16	1.03	.13	.56
Yeast, brewers dried	45	2.22	1.11	2.12	3.23	3.02	.71	.50	1.82	1.52	2.12	.50	2.31

*All values on a 90% dry matter basis.

† Average for over 80 hybrids grown in Illinois, Virginia and Texas 1972-75.

‡ Average for 15 hybrids grown in Texas 1973-75.

§ Most values were obtained from "Atlas of Nutritional Data on United States and Canadian Feeds," National Academy of Sciences (1971), and adjusted to the indicated protein level.

Average for 56 commercially grown opaque-2 corns in Virginia 1973-74 with adjusted cystine value.

Table 4. Lysine, tryptophan, threonine, isoleucine and sulfur amino acid content of selected high protein feeds.*

Percent Lysine, Tryptophan, Threonine, Isoleucine and Methionine and Cystine Content of Selected High Protein Foods											
		Lysine		Tryptophan		Threonine		Isoleucine		Methionine + cystine†	
	Protein	Feed	Protein	Feed	Protein	Feed	Protein	Feed	Protein	Feed	Protein
		percent									
Fish meal, menhaden	60	4.60	7.67	.71	1.18	2.67	4.45	2.99	4.98	2.50	4.17
Buttermilk, dry	32	2.20	6.88	.47	1.47	1.46	4.56	2.17	6.78	1.12	3.50
Whey, dried whole	12	.80	6.66	.13	1.11	1.03	8.58	.72	6.00	.32	2.67
Soybean meal, solvent	44	2.88	6.55	.55	1.25	1.87	4.25	2.32	5.27	1.13	2.57
Tankage (meat meal)	60	3.89	6.48	.58	.97	2.48	4.13	1.95	3.25	1.27	2.12
Meat and bone meal	50	2.50	5.00	.29	.58	1.81	3.62	1.71	3.42	1.27	2.54
Cottonseed meal, solvent	41	1.55	3.79	.48	1.17	1.19	2.90	1.18	2.88	.96	2.34
Peanut meal, expeller	50	1.39	2.79	.48	.96	1.13	2.26	1.47	2.94	.87	1.74
Feather meal, hydrolyzed	85	1.94	2.28	.49	.58	3.75	4.41	3.59	4.22	1.19	1.40
Corn gluten meal	42	.80	1.92	.23	.55	1.51	3.60	2.49	5.93	1.77	4.21
Sorghum gluten meal	42	.68	1.62	.39	.93	1.38	3.28	2.23	5.31	1.17	2.79

*90% dry matter basis.

† Effective total sulfur amino acid value. If cystine content was higher than methionine value, it was reduced to the methionine value since cystine can provide only 50% of the total requirement for sulfur-bearing amino acids.

lysine-supplemented diets has been good. The best current estimates for the dietary protein and lysine requirements for conventional and the lower-protein lysine supplemented diets for different weights of growing-finishing pigs are shown below:

Period	Dietary protein	Lysine requirement (percent of diet)
Starter	19	.96
10-40 lb.	16*	.90
Grower	16	.77
40-100 lb.	14*	.73
Finisher I	14	.60
100-160 lb.	12*	.56
Finisher II	13	.50
160-220 lb.	11*	.46

*Supplemental lysine would be necessary to achieve the lysine requirement at this level of protein in corn-soybean meal diets. For sorghum-soybean meal finisher diets I and II, protein levels should be increased by 1% for equal performance.

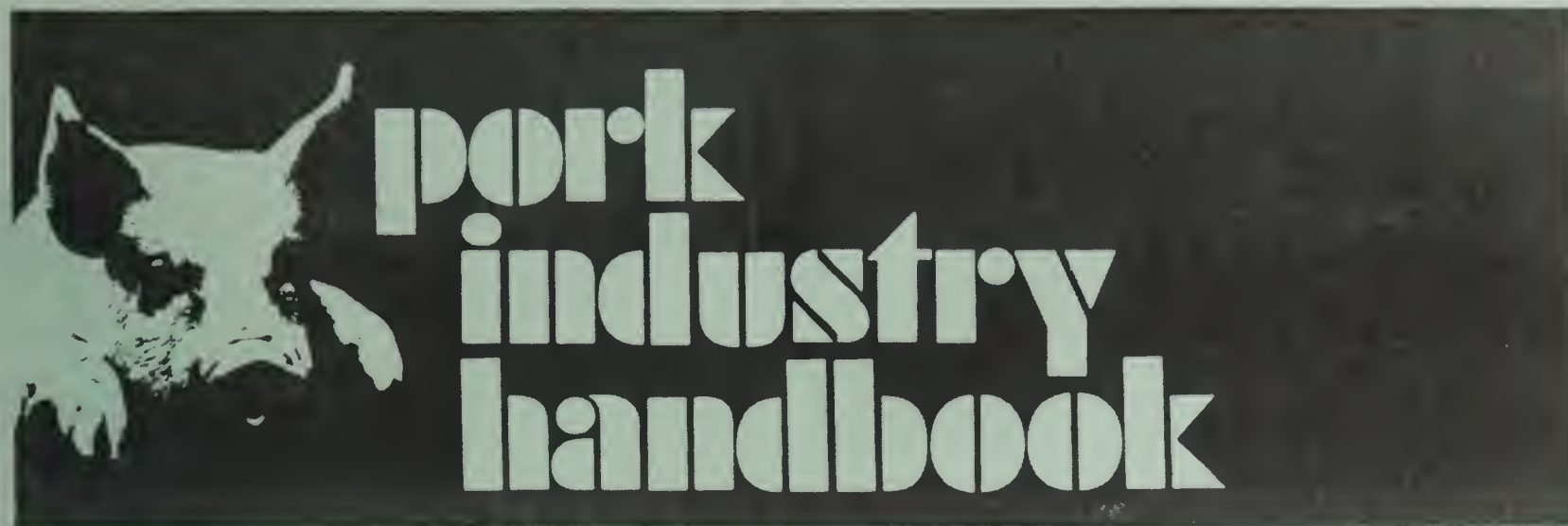
Two separate requirements are listed for starting, growing and finishing swine. These are based on the well-documented premise that the requirement for lysine,

expressed as a percentage of the diet, decreases with each reduction in dietary protein level. Therefore, when soybean meal is replaced in the diet by grain plus synthetic lysine so that the total dietary protein level is lowered by about 2%, the necessary *total concentration* of dietary lysine is reduced. Recent work at the Illinois station indicates that the lysine requirement seems to decrease by .02% of diet for each 1% decrease in the level of dietary protein.

When you use synthetic lysine, you are replacing some of the soybean meal in each ton of feed with a combination of grain (corn or sorghum) and synthetic lysine. As a thumb rule, 3 lb. feed-grade lysine monohydrochloride (78.4% L-lysine) and 97 lb. grain can replace 100 lb. 44% soybean meal per ton of ration. In cost, it is advantageous to use synthetic lysine when 3 lb. lysine monohydrochloride and 97 lb. grain can be purchased for less than 100 lb. soybean meal. However, in actual practice, the cost difference needs to be fairly wide to justify changing ration mixing procedures.

Undoubtedly, as the world demand for soybean meal for human food becomes greater, the use of supplemental amino acids will become increasingly important. The extent of their use in the years ahead will depend primarily on:

1. Availability and price of feed-grade amino acids.
2. Increased understanding of amino acid requirements with emphasis on amino acid availability and amino acid balance.



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Energy for Swine

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The value of a feedstuff is based on several factors: acceptability (how well the material will be consumed by an animal), energy availability and as a source of other nutrients (protein, vitamins, minerals). Should a swine producer buy corn or wheat or oats as a feed ingredient? This will depend primarily on the cost of these ingredients and their value as a source of energy for the animal.

The pig requires energy to maintain normal body processes, to grow and to reproduce. Energy is the major component of all swine diets, and the intake of many other nutrients is related to the energy content of the diet. Carbohydrates from cereal grains are the most abundant energy source in swine rations. Fats and oils contain more energy than carbohydrates but are used to a lesser extent. Protein may serve as an energy source only if included in the ration in excess of the animal's requirement for protein.

Definition of Energy

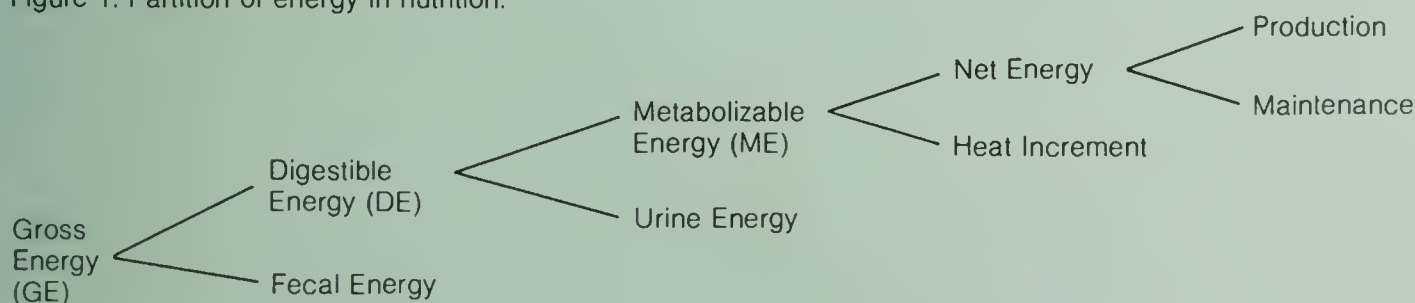
To make sound decisions in selecting feed ingredients it is desirable to have an understanding of the system by which feedstuffs are rated for their energy content and the value of these ratings toward the pig's growth and

production. The gross energy (GE) of a feed ingredient is defined as the heat produced when a substance is burned and is expressed as calories per unit weight. A calorie is the amount of heat required to raise the temperature of 1 gram of water from 14.5°C. to 15.5°C. A kilocalorie is 1,000 calories, and a megacalorie is 1,000 kilocalories. Since not all of the feed consumed is digested, some energy is lost in the fecal material (Fig. 1). GE is a poor estimate of energy for the pig.

The amount of energy remaining after subtracting the fecal energy loss from total energy intake is designated as digestible energy (DE). The difference between GE and DE may be quite large. The greater the digestible energy value (DE/GE) the greater its value as a source of energy to the animal. This is a much more meaningful measure for livestock producers. In the production and excretion of urine additional energy is lost. Digestible energy minus the urinary energy loss is termed metabolizable energy (ME).

In most cases, metabolizable energy represents approximately 95% of the digestible energy content, so the conversion from DE to ME can be made very easily. Metabolizable energy is the "usable" energy of a feed for

Figure 1. Partition of energy in nutrition.



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the pig to live and grow. Some heat is produced by metabolism of the nutrients. This is called the heat increment (HI) and can be used to keep the animal warm. The remaining energy is called net energy (NE) and is used for maintenance and production. Determination of these energy values require special equipment and/or animal feeding trials.

Major Energy Sources

The basic energy sources for swine are the cereal grains: corn, milo, barley, wheat, and their by-products. Cereal grains are high in carbohydrates, are palatable, and are highly digestible. They usually contain less protein, minerals and vitamins than swine require; therefore, the rations must be supplemented with other feeds to increase the levels of these nutrients to recommended levels. Although somewhat bulkier than the cereal grains, grain by-products have much the same characteristics as the grains from which they originate.

Corn contains less protein but more energy than the other cereals. Like all other cereals, the composition of corn is influenced by variety, growth conditions, method of harvesting, and storage. Because of its abundance and readily available energy, corn is used as the base cereal for comparing the nutritive value of other cereal grains. Milo or grain sorghum is very similar in quality to corn and can completely replace corn in swine rations. Its energy value is about 95% the value of corn except for some bird resistant varieties which may only be 80-90% of corn. Grinding is recommended since the grain is rather small and hard.

Barley contains more protein and fiber than corn, but its relative feeding value is 85-95% of corn. It is less palatable than corn. Grinding or rolling barley and pelleting the ration will improve its utilization by 5-10%.

Wheat is equal to corn in feeding value and is very palatable. But because of its use in human diets, it may be too expensive to use in swine rations.

Oats contain more protein than corn, but their value in swine rations is only 80-90% of corn because of their higher fiber content and lower energy content. They are useful in lactation rations as they are bulky and have a laxative effect.

Fats and oils such as lard, beef tallow, corn oil and soybean oil contain about 2.25 times as much energy as the cereal grains. These high energy products may be used at levels up to 5% of the ration for pigs weighing over 50 pounds. Rations containing fat may become rancid during prolonged storage or when feed is exposed to high temperatures. An antioxidant should be added to rations containing fat. In addition, use of high fat rations during the finishing period (125 pounds and above) may result in more backfat than occurs with the normal finishing rations. Because of its high cost, fat is generally not recommended for swine rations.

In selecting energy sources for swine rations, consider protein quality and content. Since the amino acids lysine, methionine, tryptophan and threonine are most likely to be limiting in a swine ration, the levels of these amino acids in cereal grains add to their overall value. Although sugar, molasses and fats or oils are good energy sources, they provide little or no protein to the ration.

The amount of feed or energy per unit of gain is not the most important factor in swine nutrition. Cost per unit of gain is more important; therefore, it is necessary to use the most economical energy sources available for swine rations. The relative feeding values shown in Table 1 can be used to determine which feed is cheapest. For example, if corn costs 5.0 cents per pound, barley is worth about 4.5 cents ($5.0¢ \times 90\%$) per pound (\$2.16/bu.). If barley can be purchased for less than this, it is a better buy.

Fiber Content

Some energy sources are relatively high in fiber and will reduce gain and efficiency if included at excessive levels in the ration. Growing-finishing pigs 40 pounds and heavier can usually tolerate up to 5% of a high fiber feed such as alfalfa in their ration without a noticeable effect on performance. As the pig matures more and more low energy-high fiber feeds can be fed, especially to sows during gestation and post-weaning. Fiber feeds such as wheat bran and beet pulp are especially useful in gestation and lactation rations because of their laxative effects.

Moisture Content

High moisture grains contain less energy per pound of feed because of the water content. More pounds of a high moisture grain must be fed to get the same amount of dry matter consumed. Studies with most high moisture grains indicate similar performance when efficiency is measured on a dry matter basis to dried grains for growing-finishing swine when fed in a complete ration. Free choice feeding of the grain and a supplement often results in poorer efficiency.

Grinding

With the possible exception of high moisture corn, grinding improves all grains for feeding, especially the higher fiber grains such as oats or barley. Finer grinding usually results in improved efficiency, although finely ground corn tends to increase the incidence of ulcers in finishing swine. Pigs under 40 pounds get the most advantage from a fine grind.

Pelleting

Pelleting a ration may increase gains up to 5% and feed efficiency from 5 to 10%. A high energy cereal such as corn or milo will benefit less from pelleting, and fibrous feeds like barley or oats will benefit more. When a complete ration is being purchased, pelleting may be more economical than a meal. However, the advantage of pelleting probably will not offset the cost of hauling corn or milo from the farm to a pelleter and home again.

Table 1. Relative feeding values*

Ingredient (air dry)	Metabo- lizable energy Kcal/lb.	Relative feeding value vs. corn†	Maximum recommended percent of complete ration‡				Remarks
			Gesta- tion	Lacta- tion	Starter	Grow- finish	
Alfalfa meal (dehydrated)	543	45-50	90	10	0	5	Low energy, good source of B vitamins
Alfalfa meal (sun-cured)	460	30-40	50	10	0	5	Unpalatable to baby pigs
Animal fat (stabilized)	3,550	210-220	5	5	5	10	High energy, reduces dust
Bakery surplus material	1,600	75-90	40	40	20	40	High energy, about 13% fat
Barley (48 lb./bu.)	1,275	85-95	80	80	25	85	Corn substitute, lower energy
Barley (West Coast)	1,280	80-85	80	80	25	85	Corn substitute, lower energy
Beet pulp, dried	1,020	70-80	10	10	0	0	Bulky, high fiber, laxative
Buckwheat	1,220	80-90					Bulky, high fiber, laxative
Corn (yellow)	1,500	100	80	80	60	85	High energy, low lysine
Corn (high lysine)	1,520	100-105	90	90	60	90	Lysine analysis recommended
Corn and cob meal	1,200	80-90	70	10	0	0	Bulky, low energy
Corn gluten feed	1,440						
Corn grits by-product (hominy)	1,400	100-105	60	60	0	60	Subject to rancidity
Corn silage (25-30% D.M.)		20-30	90	0	0	0	Bulky, low energy, feed to mature animals only
Emmer	1,139		80-90				
French fry waste (48% D.M.)			20	0	0	20	Bulky, low energy
Millet (Proso)	1,227	90-95	80	80	60	85	Low lysine
Milo (grain sorghum)	1,425	95-100§	80	80	60	85	Low lysine
Molasses (77% D.M.)	1,060	55-65	5	5	5	5	Energy source, used for pelleting
Oats (36 lb./bu.)	1,200	80-90	70	15	0	20	Low energy, partial grain substitute
Oats (high protein)		90	70	30	20	50	Low energy, partial grain substitute
Oat groats	1,500	110-115			20		Palatable
Potatoes (22% D.M.)	370	20-25	80	0	0	30	Should be cooked, low protein
Rice grain	1,074	75	40	15	0	20	Low energy, low lysine
Rye	1,300	90	20	20	0	25	Possible ergot toxicity, low palatability
Spelt	1,182	85	40	15	0	25	Low energy, low lysine
Sugar	1,383	80-85	0	0	5	0	High palatability, no protein
Triticale	1,450	90-95	80	80	20	85	Possible ergot
Wheat, hard	1,500	100-105	80	80	60	85	Low lysine
Wheat, soft	1,500	90-95	80	80	60	85	Low lysine
Wheat, high protein	1,500	100-105	80	80	60	85	Low lysine
Wheat bran	890	60-65	30	10	0	0	Bulky, high fiber, laxative
Wheat midds	1,300	90-95	30	10	5	10	Partial grain substitute
Whey, dried	1,445	100-110	5	5	20	5	High lactose content, variable salt content

*Based on an air dry basis unless otherwise noted. High moisture feedstuffs must be converted to an air dry equivalent of 88-90% dry matter to determine energy and substitution rates. Complete data on all ingredients are not available.

† When fed at no more than maximum recommended % of complete ration.

‡ Higher levels may be fed although performance may decrease.

§ Some "bird resistant milos" are 80-90% vs. corn.



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Vitamins for Swine

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Vitamins are one of the classes of nutrients required for normal metabolism functions in the animal body. They are required in much smaller amounts than most of the other nutrients as they are not used as an energy source or a structural component. Some of the vitamins can be produced within the pig's body in sufficient quantities to meet the pig's need. Others are present in adequate amounts in feedstuffs commonly used in swine diets. However, several vitamins need to be added to swine diets to obtain optimal performance. Vitamin needs are more critical today than previously because of the use of simpler type diets containing fewer ingredients and the trend toward confinement rearing which has reduced the use of pasture. Young, lush green grass or legumes are good sources of vitamins.

Vitamins Needed

Those vitamins that should be added to swine diets can be divided into two groups.

- Fat soluble vitamins
 - Vitamin A
 - Vitamin D
 - Vitamin E
 - Vitamin K
- Water soluble vitamins (known as B complex vitamins)
 - Riboflavin or B₂
 - Pantothenic acid
 - Niacin
 - Vitamin B₁₂
 - Choline

Each of these vitamins will be briefly discussed. Recommended levels of these vitamins in swine diets are shown in Tables 1 and 2. Table 1 lists requirements for the pig from weaning to market weight, and Table 2 gives the requirements for reproducing animals as an amount per pound of diet based on a daily feed intake of 4-5 lb. during gestation and 9-12 lb. during lactation. These vitamin levels

should also be satisfactory for boars fed 6 lb. of feed daily. At feeding levels other than those indicated here, the diets should be fortified to meet the daily needs. Higher levels of vitamins have not further improved performance of swine. However, in periods of stress, such as diseases that might affect absorption of nutrients, vitamin levels could be increased.

Diets may occasionally become deficient, under unusual or stress conditions, in other vitamins—biotin, pyridoxine (B₆), folic acid and vitamin C. All of these vitamins should be present in adequate amounts when diets are composed of natural feedstuffs, and it is not recommended that they be added in routine vitamin supplementation.

Vitamin A. The vitamin A needs of swine can be met by either vitamin A or carotene. Vitamin A does not occur in plant products, but the pigment carotene can be converted to vitamin A in the intestinal wall of the pig. Good natural sources of carotene are green pastures and green leafy alfalfa hay or meal. Corn contains carotene but is not a dependable source because much may be destroyed in storage. Therefore, in formulating swine diets the carotene content of corn is disregarded. Other cereal grains are low or devoid of carotene.

Deficiency symptoms in growing pigs are incoordination of movement, weakness of the back, paralysis, night blindness and total blindness. Sows may fail to come into estrus, have a poor conception rate, resorb their fetuses and have weak pigs at birth or pigs born dead with various deformities. Sterility may occur in boars.

Vitamin D. Swine that have daily access to sunlight produce vitamin D by irradiation. However, fortification of diets with vitamin D is necessary when pigs are fed in confinement. Also, most feedstuffs are practically devoid of vitamin D except for sun-cured hays. Both vitamin D₂, the

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form found in plant products, and D₃, the animal product form, have the same value for swine.

Vitamin D is needed for efficient absorption and metabolism of calcium and phosphorus and therefore is required for normal calcification of bones. A deficiency in young pigs results in rickets, stiffness and lameness, enlargement of the joints and general unthriftiness. In mature animals, fractures of the bones are common.

Vitamin E. A decline in use of pasture for pigs and an increase in artificial drying of grains has resulted in a lowering of vitamin E intake and an increase in the occurrence of deficiency symptoms. Grains low in selenium increase the need for vitamin E as the dietary level of one of these nutrients affects the requirement for the other.

Signs of vitamin E deficiency in the growing pig are sudden death, jaundice, edema, white muscles and liver necrosis. Pregnant sows may have a higher level of embryonic death, and pigs nursing sows deficient in vitamin E may show muscular incoordination.

Vitamin K. Although vitamin K occurs in many natural feedstuffs and is also synthesized by intestinal microflora of the pig, a deficiency in practical diets has been demonstrated. The deficiency is frequently associated with moldy feeds. Its characteristics are hemorrhaging and prolonged blood clotting time but may also include blood tinged urine, lameness and listlessness. Vitamin K can be supplied by using 2.5% dehydrated alfalfa meal or by a synthetic product called menadione sodium bisulfite at a level of 2 gm. per ton of feed.

Riboflavin (B₂). Cereal grains and plant by-products such as soybean meal are relatively poor sources of this B vitamin. It functions in the body as a constituent of several enzyme systems. Therefore, a deficiency of riboflavin results in a wide variety of symptoms. In growing pigs, a deficiency may cause loss of appetite, stiffness, dermatitis and lowered growth rate. Poor conception and reproduction have been noted in sows fed riboflavin-deficient rations. Pigs may be born prematurely, dead or too weak to survive.

Pantothenic Acid. Corn and soybean meal diets will be deficient in pantothenic acid, another vitamin of the B complex. A deficiency may result in lowered fertility, reduced growth rate, diarrhea and an incoordinated, wobbly or high stepping gait (called goosestepping). Many of these symptoms are similar to those observed from other deficiencies and indicate that in practical feeding situations it is difficult to determine which vitamin may be lacking. In fact, in many cases it is a combination of vitamins in inadequate amounts that causes the problems that may be observed.

Niacin. Although niacin is present in adequate amounts in most cereal grains, it exists in a bound form that is largely unavailable to the pig. The protein source and content of the diet can also affect the dietary need for niacin because an excess of the amino acid tryptophan can be converted into niacin. Slow growth, diarrhea, dermatitis, loss of hair and occasional vomiting are deficiency symptoms. Alfalfa meal and good pasture are good natural sources of riboflavin, pantothenic acid and niacin.

Vitamin B₁₂. The cereal grains and plant products are poor sources of B₁₂, but the animal products are good sources. The requirement for this vitamin is approximately one-thousandth of the amount of the other B vitamins discussed. Signs of a deficiency are reduced growth rate and anemia.

Choline. The specific requirement for choline has not been determined. The need for choline is increased in diets low in the amino acid methionine. Recent research has indicated that supplemental choline increased litter size when gestating sows were fed corn-soybean meal diets. Choline deficiency has been implicated by some as the cause of spraddle legs in newborn pigs. However, this has not been proved in research where sows are fed practical type diets during gestation. Apparently, there are other causes of the spraddle leg condition.

Synthetic Vitamins

Since the natural sources of the vitamins listed may not be present in swine diets, it is recommended that a vitamin supplement be added. Synthetic vitamins are produced by many companies and are sold individually or in various combinations of vitamins or as vitamin-mineral combinations. Often these can be purchased in 5 or 10-lb. quantities that can be added to 1 ton of feed. An example of a synthetic vitamin premix is shown in Table 3. It contains all of the vitamins needed to be added to swine starter, gestation or lactation diets when 10 lb. are added per ton of feed, and for growing and finishing diets by including 6 lb. per ton. Commercial protein supplements generally contain supplemental vitamins. Check to see if the levels are adequate. If not, add vitamins that are needed in necessary amounts.

Mixing Instructions

The vitamin premix should be purchased from a commercial company. These suppliers have much better quality control and mixing facilities to handle the small quantities of vitamins that are required. Purchase no more than what will be used in 3-6 months (use in 3 months in hot, humid areas) and store in a dry, cool area to reduce storage losses. Mix only enough feed for 3-4 weeks as certain combinations of ingredients can increase vitamin losses over time.

Special care should be taken when mixing the vitamin premix to obtain a thorough dispersion throughout the feed. One method is to mix the vitamin premix for 1 ton of feed with about 20-40 lb. of finely ground corn and then add this total mixture to the mixer.

Table 1. Recommended vitamin additions for pigs, weaning to market (amount per pound of diet)

Vitamin	Starter diet	Grower-finisher diet
Vitamin A, IU	2,000	1,200
Vitamin D, IU	200	120
Vitamin E, IU	5	5
Vitamin K, mg.	1	1
Riboflavin, mg.	1.5	1.2
Pantothenic acid, mg.	8	6
Niacin, mg.	10	8
Vitamin B ₁₂ , mcg.	10	6
Choline, mg.	85	50

Table 3. Example of vitamin premix to be added to 1 ton of feed*

Ingredient	Concentration (per 10 lb.)
Vitamin A	4,000,000 IU
Vitamin D	400,000 IU
Vitamin E	17,000 IU
Vitamin K	3.33 gm.
Riboflavin	4 gm.
Pantothenic acid	20 gm.
Niacin	27 gm.
Vitamin B ₁₂	20 mg.
Choline	170 gm.
Carrier (such as ground corn)	To bring total to 10 lb.

*This premix could be used at 10 lb. per ton for gestation, lactation and starter diets and 6 lb. per ton for growing and finishing diets. To meet the recommended level of choline in the gestation ration, add 3 lb. of choline chloride (25% choline) per ton of gestation ration.

Table 2. Recommended vitamin additions for reproduction*

Vitamin	Amount per pound of diet
Vitamin A, IU	2,000
Vitamin D, IU	200
Vitamin E, IU	5
Vitamin K, mg.	1
Riboflavin, mg.	2
Pantothenic acid, mg.	8
Niacin, mg.	10
Vitamin B ₁₂ , mcg.	10
Choline, mg.	250

*Recommendations based on daily feed intake of 4-5 lb. for gestation and 9-12 lb. during lactation.



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Minerals for Swine

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Minerals serve a variety of structural and metabolic functions in swine. The number of inorganic elements required in the diet probably exceeds 20; these include calcium, phosphorus, sodium, chlorine, potassium, magnesium, sulfur, iron, zinc, copper, manganese, iodine and selenium. Cobalt is required as a part of vitamin B₁₂. Other elements shown essential for chicks or laboratory animals, and probably required by swine, include molybdenum, fluorine, chromium, silicon, nickel, vanadium, tin and arsenic. Whether these last-mentioned elements will be of practical significance awaits further research. Most of them are believed present in adequate quantities in natural feedstuffs. However, the use of simpler swine diets with few ingredients may necessitate consideration of their importance in the future. Currently, the following 10 mineral elements are regularly added to swine diets.

Minerals Needed

Those minerals that should be added to swine diets can be divided into two groups.

Macrominerals

Calcium
Phosphorus
Sodium
Chlorine

Microminerals

Iron
Zinc
Iodine
Selenium
Copper
Manganese

Each of these minerals will be discussed briefly. Minimal National Research Council (NRC) requirement

levels of these minerals in swine diets are shown in Tables 1 and 2.

Table 1 lists requirements for the pig from birth to market weight and Table 2 gives the requirements for reproducing animals as a concentration in the diet based on a daily feed intake of not less than 4 lb. during gestation and not less than 9 lb. during lactation. These mineral levels should also be satisfactory for boars fed 6 lb. of feed daily. At other feeding levels, some adjustment of mineral concentration may be necessary. However, excesses of minerals are not normally helpful and frequently create imbalances that impair performance.

Calcium and phosphorus. About 99% of the calcium and 80% of the phosphorus in the body is found in the skeleton and teeth. These two elements are obviously important in skeletal structure, but the amounts in soft tissues also have vital functions, such as the role of calcium in blood clotting and in muscle contraction and of phosphorus in energy metabolism.

Corn, sorghum grain, and soybean meal are low in calcium and available phosphorus. In grains and plant protein supplements, about 2/3 of the phosphorus is found as phytate. This is an organic form that varies in availability from 20% to 60% as compared to phosphorus in dicalcium phosphate. Meat and bone meal, tankage and fish meal contain liberal quantities of calcium and available phosphorus.

Signs of calcium or phosphorus deficiency include poor growth, impaired bone mineralization (rickets in young pigs, demineralized bone in adults), and fractured ribs and vertebrae.

Excess calcium (above 1%) may precipitate a zinc deficiency and impair bone mineralization. An optimal calcium-phosphorus ratio is from 1:1 to 1.5:1.

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Table 1. Required minimal mineral concentrations in diets for pigs from birth to market weight (% or ppm).*

Mineral	Liveweight (lb.)					
	2-10	10-20	20-45	45-80	80-130	130-220
Calcium,%	0.90	0.80	0.65	0.60	0.55	0.50
Phosphorus,%†	0.70	0.60	0.55	0.50	0.45	0.40
Sodium,%	0.10	0.10	0.10	0.10	0.10	0.10
Chlorine,%	0.13	0.13	0.13	0.13	0.13	0.13
Potassium,%	0.30	0.26	0.26	0.23	0.20	0.17
Magnesium,%	0.04	0.04	0.04	0.04	0.04	0.04
Iron, ppm	150	140	80	60	50	40
Zinc, ppm	100	100	80	60	50	50
Copper, ppm	6	6	5	4	3	3
Manganese, ppm	4	4	3	2	2	2
Iodine, ppm	0.14	0.14	0.14	0.14	0.14	0.14
Selenium, ppm	0.15	0.15	0.15	0.15	0.15	0.15

*Adapted from NRC. 1978. Nutrient Requirements of Swine. National Academy of Sciences, Washington, D.C.

†At least 40% of the phosphorus should be provided by inorganic sources.

Table 2. Required minimal mineral concentrations in diets for reproducing swine (% or ppm).*

Mineral	Bred gilts & sows	Lactating gilts & sows
	Young & adult boars	
Calcium,%	0.75	0.75
Phosphorus,%†	0.50	0.50
Sodium,%	0.15	0.20
Chlorine,%	0.25	0.30
Potassium,%	0.20	0.20
Magnesium,%	0.04	0.04
Iron, ppm	80	80
Zinc, ppm	50	50
Copper, ppm	5	5
Manganese, ppm	10	10
Iodine, ppm	0.14	0.14
Selenium, ppm	0.10	0.10

*Adapted from NRC. 1978. Nutrient Requirements of Swine. National Academy of Sciences, Washington, D.C.

†At least 40% of the phosphorus should be provided by inorganic sources.

Sodium and chlorine. These two elements assist in maintaining osmotic pressure of body fluids. Sodium is involved in nerve function, and chlorine is found in hydrochloric acid produced in the stomach. Grains and plant protein supplements are low in these elements, but the needs of the growing-finishing pig can be met by adding 0.20-0.25% salt (sodium chloride) to the diet. Little research has been done on the needs of reproducing animals, so until further information is available, it is recommended that 0.4% salt be added to diets of boars and pregnant females and 0.5% to diets of lactating females.

A deficiency of sodium and chlorine reduces appetite and impairs growth.

High levels of salt can be tolerated if adequate drinking water is available. However, if water is restricted, as little as 2.0% dietary salt has resulted in toxic signs of nervousness, weakness, staggering, epileptiform seizures and death.

Iron. Iron is required for hemoglobin, myoglobin and a number of iron-containing enzymes. The baby pig is born with a limited supply of iron, and since sow's milk is also low in this element, iron-deficiency anemia is a common problem in the baby pig. An intramuscular injection of 100-200 mg. iron from iron dextran or iron dextrin is commonly given at 1-3 days of age to prevent this problem.

Although corn and grain sorghum are also low in iron, supplemental protein sources have more adequate supplies, and consumption of unsupplemented corn-soybean meal diets or grain sorghum-soybean meal diets would not normally lead to severe anemia. However, generous supplies of certain other elements such as copper or zinc may increase the need for supplemental iron, and thus, iron supplements are recommended. Ferrous sulfate is an effective dietary iron supplement with high iron availability. Ferric oxide is ineffective as an iron source, and the availability of iron in ferrous carbonate varies with the physical form but is generally less than that in ferrous sulfate.

Signs of iron deficiency include small, hemoglobin-deficient red blood cells, pale mucous membranes, chalky skin color in white-skinned pigs, enlarged heart, spasmodic breathing after exercise, and decreased resistance to certain bacterial infections.

Iron in excess can be toxic, and large doses may produce nervous lesions resulting in incoordination and convulsions. The lining of the gastrointestinal tract is frequently damaged sufficiently to impair absorption of nutrients. Continuous feeding of diets containing 5,000 ppm iron from ferrous sulfate and marginal in phosphorus resulted in rickets in 4 weeks.

Zinc. Zinc is important for the function of several enzymes. The concentration of this element is low in grains and plant protein supplements, but more nearly adequate in animal products such as meat and bone meal. In grains and oil

seed meals much of the zinc is associated with phytate and is poorly available. Forms of supplemental zinc utilized by swine include zinc oxide, zinc sulfate, and zinc carbonate. Excess calcium in the diet increases the zinc requirement.

Zinc deficiency results in loss of appetite, poor growth, parakeratosis, and impaired sexual development in boars.

Zinc toxicity has been produced by 2,000 ppm zinc from zinc carbonate in the diet. Toxic signs included growth depression, inflammation of the gastrointestinal tract, arthritis, and hemorrhage in the axillary space. Over a short term, 1,000 ppm zinc did not produce toxic signs.

Iodine. Iodine is a component of thyroid hormones and thus affects metabolic rate. Much of the inland glaciated area of the United States is iodine deficient because this element has been leached from the soil. As a consequence, feeds grown on these soils are also iodine deficient. In addition, certain feeds contain goitrogens that increase the iodine requirement. The iodine requirement may also be increased by excessive dietary concentrations of arsenic and fluoride. Meat and bone meal cannot be relied upon as a source of iodine, but fish meal contains adequate amounts.

Iodine deficiency signs have been observed in pigs born to deficient sows and include weakness, hairlessness, thick pulpy skins, goiter and death.

Pigs are more tolerant than cattle of excess iodine, and the minimal toxic dietary level lies between 400 and 800 ppm. Growth rate, feed intake, hemoglobin concentration and liver iron levels are depressed. Supplementary iron has been shown to partially alleviate these effects.

Selenium. Selenium is a component of an enzyme that protects cell membranes against oxidative damage such as that which results in white muscle disease. Many soils in the United States are deficient in this element, or its availability is low, for example, on acid soils. As a consequence, selenium concentration in feedstuffs produced in these regions may be deficient for swine. The need for supplemental selenium is related to vitamin E intake. With decreased use of pasture (a good source of vitamin E) and artificial drying of grains (which may result in destruction of vitamin E), supplemental selenium has become more important. The amount that may be added to swine diets is regulated by the U.S. Food and Drug Administration and is limited to 0.1 ppm selenium from sodium selenite or sodium selenate.

Signs of selenium deficiency include sudden death (particularly in weaned pigs), unusually pale areas and dystrophy of muscle (white muscle disease), liver necrosis, edema of the mesentery of the spiral colon, lungs and subcutaneous tissues, and impaired reproduction.

Selenium toxicity has been produced by 5-8 ppm of selenium in the diet. Higher levels result in loss of appetite, depressed growth, loss of hair, stiffness and pain upon movement, separation of the hooves, erosion of the joints, atrophy of the heart ("dish-rag" heart), cirrhosis of the liver, anemia, and impaired development of embryos. High protein diets and arsenic salts offer some protection.

Copper. Copper is required for the function of certain enzymes, and it favorably influences iron absorption from the intestinal tract and iron mobilization from stores in the liver. The minimal nutritional requirement for copper has been studied only with the baby pig on a purified diet. If the need for the other pigs on commercial diets is about the same, most feed ingredients will probably supply enough. However, since information on copper requirements is limited, some supplemental copper (6 ppm) is

recommended. High levels of dietary copper (125-250 ppm) have been used to stimulate growth, but this is considered an antibiotic or pharmacological effect.

Signs of copper deficiency include small, hemoglobin-deficient red blood cells, reduced growth, nervous disorders, incoordination and defective bone formation.

Copper toxicity has been produced by feeding 250 ppm copper throughout the growing-finishing period when the diet contained only modest (but requirement) levels of zinc and iron. Extra zinc and iron prevented the toxicity. Toxic signs included impaired growth, anemia, jaundice and death.

Manganese. Manganese is necessary for the function of a number of enzymes, some of which influence energy metabolism, bone development and reproduction. The minimal requirements have not been well defined, and there is considerable disagreement over the amount needed. Some of the disagreement may be a result of lower manganese availability in natural feedstuffs than in purified experimental diets. Until more information is available, a manganese supplement (12 ppm) is recommended.

Signs of manganese deficiency include impaired growth, lameness, enlarged hocks, crooked and shortened legs, absence of or irregular estrus, poor mammary development and lactation, and birth of small, weak pigs with an impaired sense of balance.

Manganese at 4,000 ppm in the diet results in depressed feed intake, reduced growth rate, stiffness and a stilted gait.

Mineral Supplements

Calcium and phosphorus. The ingredients used in swine diets vary widely in mineral content. Corn, sorghum grain and soybean meal are particularly low in calcium. Feed grains contain phosphorus, but it is largely phytin phosphorous, which may be poorly utilized by swine. Corn-soybean meal diets and sorghum grain-soybean meal diets must therefore be supplemented with both calcium and inorganic phosphorus. For specific suggestions see PIH-23, Swine Rations.

Feeds of animal origin such as meat and bone meal, tankage or fish meal are quite high in calcium and available phosphorus. Thus, the level of supplemental calcium and phosphorus should be reduced as feeds of animal origin replace soybean meal in the swine diet.

The standard ingredients for supplying supplemental calcium and phosphorus in the swine diet are limestone and either dicalcium phosphate or defluorinated rock phosphate. Twenty pounds of limestone and 20 lb. of dicalcium phosphate per ton of a corn-soybean meal diet will meet minimum NRC calcium and phosphorus requirements of growing-finishing pigs. For sows and gilts limited to 4 lb. of feed during gestation, dicalcium phosphate should be increased to 30 lb. per ton. However, dicalcium phosphate is often in short supply, and substitutions must be made. Table 3 lists a number of phosphorus sources which may be used to replace dicalcium phosphate. It should be noted that all of the alternative ingredients supply both calcium and phosphorus. Thus, the quantity of limestone in the diet must also be adjusted when alternate phosphorus supplements are used. The center two columns in Table 3 list the correction factors that must be applied to the pounds of limestone and dicalcium phosphate in the diet when substitutions are made.

For example, if steamed bone meal were used as the only phosphorus supplement in a ton of swine grower diet where 20 lb. of dicalcium phosphate and 20 lb. of limestone

Table 3. Feed Ingredients that supply calcium or calcium and phosphorus.

	%Ca	%P	Lb. needed to equal P in 1 lb. of dical phos.	Lb. change in limestone * for each lb. change of dical phos.	Lb. of dical substitute and lime- stone per ton of feed when com- pletely replacing dical	
					Dical subs.	Limestone*
Grd. limestone (Ca carbonate)	38*	0				
Dical phos.	22	18				
Monocal phos	16	24	0.75	+.25	15	25
Mono-dical phos	18	21	0.86	+.20	17	24
Defluor rock phos	32	18	1.00	-.25	20	15
Steam bone meal	24	12	1.50	-.35	30	13
Trical phos	38	18	1.00	-.40	20	12
Meat & bone meal	10	5	3.60	-.35	72	13
Tankage	6	3	6.00	-.35	120	13
Fish meal	6	3	6.00	-.35	120	13

*If ground limestone contains 35% Ca, multiply pounds change in limestone by 38/35 or 1.09.

had been used, the factor 1.5 would be multiplied by the 20 lb. of dicalcium phosphate being replaced, giving 30 lb. of steamed bone meal needed ($1.5 \times 20 = 30$). When 30 lb. of steamed bone meal replaced 20 lb. of dicalcium phosphate, the amount of limestone should be adjusted by the factor -0.35 multiplied by the pounds of dicalcium phosphate replaced ($-0.35 \times 20 = -7$). Thus, the amount of limestone needed would be the original 20 lb. minus 7, or 13 lb. ($20 - 7 = 13$). The recalculated amounts of calcium and phosphorus supplements to add to a ton of swine grower diet would be as follows:

30 lb. steamed bone meal
13 lb. limestone

These quantities are presented in the last two columns of Table 3 representing calculated values when dicalcium phosphate is completely replaced by an alternate phosphorus source. The technique used in calculating these values is also appropriate where only part of the dicalcium phosphate is replaced. For example, if 10 lb. of dicalcium phosphate is to be replaced by steamed bone meal, the calcium and phosphorus supplements per ton of swine grower diet would be as follows:

10 lb. dicalcium phosphate
15 lb. steamed bone meal
16.5 lb. limestone

Sodium and chlorine. The need for these two elements can be met by adding 5-10 lb. of salt (sodium chloride) per ton of a growing-finishing diet and 10 lb. of salt per ton of gestation, lactation or boar diets.

Table 4. Example of a micromineral premix (3 lb.) to be added to 1 ton of feed.

Ingredient	Concentration (per 3 lb.)
Iron	40 gm.
Zinc	55 gm.
Copper	5.5 gm.
Manganese	11 gm.
Iodine	0.11 gm.
Selenium	90.8 mg.
Carrier (such as ground corn)	To bring total to 3 lb.

Suggested ingredients: ferrous sulfate; zinc oxide, carbonate or sulfate; copper oxide, hydroxide, carbonate or sulfate; manganous oxide, carbonate or sulfate; pentacalcium orthoperiodate, calcium or potassium iodate; sodium selenite or selenate.

Microminerals. The need for supplemental iron, zinc, iodine, copper and manganese can usually be met by adding 10 lb. of a commercial swine trace mineral salt (0.5-0.8% zinc) per ton of swine diet. Selenium supplements must usually be provided separately, and the addition of 1 lb. per ton of a supplement containing 90.8 mg. selenium per pound will meet nutritional and legal requirements. If a micromineral premix (separate from salt) is preferred, an example formulation is presented in Table 4 (or see PIH-23).